SCIENTIFIC AMERICAN
SUPPLEMENT

Two carpenter ants feeding on the sweet excretion of the plant lice which they maintain for this purpose

FAMILIAR INSECTS THROUGH THE CAMERA (see page 248)

Ultraviolet Energy[*]

A Study of the Short Light-Waves from Economic Viewpoints

By M. Luckiesh, of the Nela Research Laboratory

Since the discovery of ultraviolet rays, more than a century ago, their production and properties have been subjected to a great deal of investigation. However, notwithstanding the extensive literature on the subject, we must agree with Sheppard, who says in his book on Photo-chemistry: "We are only at the beginning of the conscious utilization of the powers of light, as distinct from the unconscious enjoyment of them." Owing to the many unique properties of these invisible rays they are extremely valuable in certain scientific investigations, tests, and industrial processes, and it appears certain that, with the progress of the development of sources of ultraviolet rays, and of media transparent to them, the usefulness of ultraviolet energy will be rapidly extended. The problems in which these unique properties may be utilized are so manifold, it appears that a general discussion of the subject may be welcomed at this time. For the sake of clearness in the following discussions, the spectrum will be divided arbitrarily, as follows:

Visible spectrum extends to wave-lengths slightly shorter than 400μμ.

Near ultraviolet will designate the region between 400μμ and 300μμ.

This may be said to be the extent of the ultraviolet spectrum ordinarily encountered because clear glass is, in general, opaque to rays of shorter wave-length.

Middle ultraviolet will designate the region between 300μμ and 200μμ.

Schumann region is that from 200μμ to beyond 100μμ. This region has been studied elaborately by Lyman[1], who has revealed the spectrum somewhat beyond 100μμ.

It is understood that some of these divisions and limits have been chosen arbitrarily for the sake of convenience in the present discussion.

TRANSPARENCY OF MEDIA.

The transparency of various media for ultraviolet rays is of importance from the standpoint of the production, measurement, and utilization of this energy. Enclosing media and optical parts must be transparent to the rays to be utilized. Ofttimes filters are desired for isolating certain spectral regions and in many other ways it is of interest to know the spectral transmission characteristics of various media. Of course, the thickness of the medium is an important factor, but where this is not mentioned in the following discussion, ordinary moderate thicknesses will be assumed. In this general discussion it is out of the question to take up this and many other details.

Clear glass varies in its spectral characteristic in the ultraviolet region, depending upon its composition. Most ordinary clear glasses are quite transparent down to 350μμ, but they usually decrease in transparency from this point until they become practically opaque at about 300μμ. The Jena works developed a glass (uviol) which transmitted quite freely down to 300μμ. Fritsch[2] has given a formula for a durable glass which he claimed to be transparent as far as 185μμ. He recommended 6 grams of CaFl₂ mixed with 14 grams of B₂O₃ in powdered form. This was melted in a platinum furnace crucible and poured out on an unheated sheet of platinum.

Fused quartz transmits freely to about 220μμ. Crystal quartz is transparent as far as 180μμ. It is thus seen that quartz is only useful for the middle and near ultraviolet regions.

Fluospar is not only transparent to these regions, but also to nearly all the Schumann region, its transparency extending to 120μμ.

Air absorbs the rays in the Schumann region quite powerfully. Therefore, for most practical purposes quartz is satisfactory. An air-path 1 cm. long is opaque to radiant energy of wave-lengths shorter than about 170μμ. The solar spectrum, even when photographed at high altitudes, ends at about 290μμ, indicating the presence of media in the earth's atmosphere or in that of the sun which are opaque to the rays in the middle and Schumann regions. Lyman presents data on the absorption of gases which may be of interest in this connection.

Snow reflects the near ultraviolet rays almost completely.

A thin veil of smoke is opaque to the middle and Schumann regions.

Gypsum, celestite, borite, sugar crystals, calcite and alum are opaque to most of the Schumann region, their transparencies ending in the neighborhood of 170μμ.

Mica strongly absorbs the rays of short wave-length. Rock salt is of high transparency at 185μμ.

Gelatine strongly absorbs the rays of shorter wave-length than 200μμ and therefore, for photographic work in this region, non-gelatine plates must be used. It is obvious that an evacuated space also must be provided owing to the absorption by the air.

Pure water is quite transparent to the middle and near regions.

The above-mentioned substances are of interest largely owing to their transparency but certain filters are of special interest owing to their spectral absorption characteristics.

Many optical glasses which are nearly colorless or of a yellowish-green or yellowish tint effectively absorb nearly all the ultraviolet region. Uranium glass is very effective in this respect and by virtue of its fluorescence it is useful in exploring an ultraviolet spectrum especially for such a purpose as focussing a spectrograph. Quartz spectroscopes are sometimes equipped with such fluorescent screens in the eye-piece for visually inspecting the ultraviolet spectrum. A solution of quinine sulphate or of aesculine effectively absorbs the ultraviolet rays and both fluoresce.

Dense cobalt-blue glass combined with an aqueous solution of CuSO₄ (which absorbs the red band transmitted by the cobalt glass) isolates the near ultraviolet and violet rays.

Nitroso-dimethyl-aniline dissolved in water is fairly transparent between 280μμ and 400μμ. This may be incorporated in gelatine (6 grams of gelatine to 100 grams of water heated to about 50 deg. C.) and flowed on a glass or quartz plate. The best strength of this filter is one which just eliminates the blue and violet light. This filter may be combined with blue uviol glass and an aqueous solution of CuSO₄ for the purpose of isolating the near ultraviolet. In case the glass elements of such a combination are unsatisfactory, quartz plates may be used and a dense solution of methyl violet or other dense violet dye may be substituted for the blue uviol glass.

Many combinations of aniline dye solutions or gelatine filters may be used for isolating the near ultraviolet.[3] For isolating portions of the middle and Schumann regions various gases and other media may be used. For example, Peskov[4] studied the spectral absorptions of chlorine and bromine and found that, by varying a mixture of these two gases, he could isolate regions of the spectrum as narrow as 240μμ to 250μμ. These mixtures were found to follow Beer's law and, therefore, after having obtained the requisite quantitative data, the mixture for filtering a certain spectral range could be calculated.

Metallic silver is opaque to the ultraviolet except for a narrow range near 300μμ to 340μμ. Colloidal silver appears to have a spectral transmission characteristic which differs from that of the metallic film.

Absalom[5] dissolved such metals as K, Na, Li, Cs, Rb, Ba, and Sr in ammonia and obtained blue solutions which had valuable properties as ultraviolet filters. These solutions were quite fugitive but with dry ammonia and freshly scraped metal, Cottrell obtained blue solutions lasting as long as several years. A general result of Absalom's work was that transparency far into the ultraviolet is much more commonly met with in the case of color due to colloidal metals than in the case of ordinary colored salts or aniline dyes. The limit of transmission for liquid ammonia is at about 240μμ. In general for these blue solutions total absorption began in the neighborhood of 245μμ.

Absalom used an arc between copper poles and a small quartz spectrograph and thus was able to photograph a spectral range between 500μμ and 225μμ. He presented the following wave-lengths in μμ as those at which complete absorption commences:

Natural rock salt	Beyond 225μμ
Natural rock salt colored by cathode rays	
	Beyond 225μμ
Natural rock salt colored blue by cathode rays	
	Beyond 225
Sylvite, white	Beyond 225
Chili saltpetre, ordinary white variety	351.2
Chili saltpetre, violet	324.8

Fluorspar, colored deep violet by cathode rays

	Beyond 225μμ
Diamond yellow	320
Diamond blue	315
Kunzite	305
Garnet	402.3
Zircon (hyacinth) red-brown	261.8
Zircon, decolorized by heat	244.2
Zircon, green	402.3
Zircon, yellow	402.3
Topaz, pale yellow	261.8
Topaz, dark yellow	229.4
Topaz, pale pink-brown	261.8
Topaz, blue	296.1
Emerald	320
Ruby	300
Tourmaline, green	351.2
Tourmaline, green-yellow	300
Tourmaline, pink	306.4
Spinel, blue	402.3
Spinel, purple	324.8
Spinel, pink	300
Kyanite, blue	320
Beryle, blue	327.4
Cordierite, blue-purple	324.8
Cairngorm	324.8

SOURCES.

There are many sources of ultraviolet energy but few are powerful enough to be widely useful. The ideal source, which emits a continuous non-banded spectrum of high intensity throughout the entire ultraviolet region, does not exist.

The incandescent solids such as the latest Mazda lamps emit a continuous spectrum of appreciable intensity through only a part of the near ultraviolet region. The sun emits a continuous spectrum of fair intensity as far as 295μμ but this spectrum has many dark lines due chiefly to selective absorption by the sun's atmosphere.

The limelight and burning magnesium ribbon emit appreciable ultraviolet energy, but not in sufficient amounts to offset the inconvenience attending their use. Of the present-day sources this leaves only the arcs, sparks, and vacuum tubes available for the more general work.

The mercury arc in glass is obviously limited in usefulness by the absorption of the glass. Consequently the mercury arc in quartz tubes is much more applicable to ultraviolet work. This arc has the great advantage of steadiness but the disadvantage in some cases of large gaps in its line spectrum. Investigation has shown that the output of ultraviolet energy decreases materially with the time that the arc has been used, some old quartz mercury arcs being only half as effective as they were when new. However for many problems this arc is very satisfactory.

The ordinary carbon arc emits a considerable quantity of ultraviolet rays in the near and middle regions but there are other arcs which are far superior to it and are no less convenient to use. The magnetic arc has a positive pole of copper and a negative pole consisting of a sheet steel tube packed with a fine powder consisting principally of oxides of iron (magnetite), titanium, and chromium. This arc is fairly rich in ultraviolet rays.

Measured from the standpoint of total ultraviolet energy per unit of visual intensity of illumination, Bell[6] ranks these sources in the following order: magnetite arc, old mercury arc, new mercury arc, and carbon arc, the last two being about equal on this basis and more than twice as rich in ultraviolet rays as the first two. This basis is of interest in lighting but it should be noted that, in general, the ultraviolet output per watt of energy input is generally of interest.

Some spectra of interest will be found in Reference 3 and many emission spectra are to be found in the Atlas of Emission Spectra by Hagenbach and Konen. Atlases of absorption spectra have been prepared by Uhler and Wood and by Mees which show the absorption spectra of many soluble coloring media.

Lyman[1] has shown that the mercury arc emits a strong line near 185μμ which will be very effective, in some reactions, with a short air-path but only feeble with a long air-path owing to the absorption by the air. This indicates that, when dealing with radiation of such short wave-lengths, very different results may be obtained with the same source depending upon the distance of the reaction from the source.

[*]From Metallurgical and Chemical Engineering.

[1]Spectroscopy of the Extreme Ultraviolet, Longmans, Green & Co., 1914.

[2]Phys. Zeit. 8, 1907, p. 518.

[3]M. Luckiesh, Color and Its Application, p. 51.

[4]Jour. Phys. Chem. 21, 1917, p. 386.

[5]Phil. Mag. 33, 1917, p. 452.

[6]Elec. World, Apr. 13, 1912.

The flame arc has potential possibilities as a source of ultraviolet rays owing to the diversity of materials with which the carbons may be impregnated. It has been found that the feebly luminous flame of the ordinary carbon arc is the source of much of the short-wave ultraviolet energy emitted. The white-flame arc of high amperage, in proportion to the energy input, is the most efficient commercial source of near and middle ultraviolet energy available at present. It radiates energy quite extensively in the near and middle regions. Mott found the fading effect on dyes at a distance of 10 inches from a 28-ampere white-flame arc to be several times greater than June sunlight and that the fading results were approximately the same. Obviously there should be no rays present of shorter wave-length than $295\mu\mu$ in a dye-testing illuminant if the results are to be comparable with that of sunlight. Such a source as the white flame arc could be screened by a thin glass shell of a proper spectral transparency in order to eliminate rays of those wave-lengths not found in daylight.

The blue flame arc emits ultraviolet energy very strongly.

It is a simple matter to construct an arc which will emit ultraviolet energy strongly, provided hand-control is satisfactory. An iron rod and a carbon rod may be employed successfully for the two poles, however, two iron rods may answer the purpose very well. These poles may be kept cool effectively by means of heavy brass or copper sleeves which may be moved along the iron rods as the latter are consumed. A particularly successful iron arc of this type can be made in a few hours. The upper pole, which is negative, may be an iron rod about $\frac{1}{4}$-in. in diameter. This is surrounded by a movable but well-fitted solid sleeve of copper about one inch in diameter. The lower pole may be an iron rod about $\frac{1}{2}$-inch in diameter with the end in the form of a shallow dish. One pole should be adjustable vertically. In preparing the arc a bead of molten metal is developed in the dished end of the lower electrode, the latter becoming oxidized, which apparently decreases the rapidity of deterioration. The upper electrode is well cooled and the arc is maintained very steadily between the molten bead of iron and the upper solid electrode. The writer has had such an arc operate a rather high current density for thirty minutes without any adjustment. The dimensions may be increased to meet the requirements. It is not a difficult matter to make various simple arcs which are quite satisfactory for a great deal of work.

For many purposes the spark between metallic electrodes is very satisfactory, but, in general, the sparks cannot compete with the arcs in quantity of ultraviolet energy emitted. Various forms of spark gaps have been employed depending upon the requirements; usually steadiness of position of the spark and shadows of the poles are the factors which determine the shape of the gap. A short spark obtained from a transformer may be satisfactory or it may be fattened by using a condenser. A high frequency spark may sometimes be desirable. The kind of spark obtained depends upon dimensions and electrical relations and obviously these may be widely varied. The metals commonly employed for the poles of spark gaps are aluminium, zinc, iron, copper, and cadmium, although any other may be satisfactory, depending upon its spectrum and upon the specific requirements.

The spectra of electrically excited gases confined at low pressures in transparent tubes have been extensively studied but such vacuum discharge tubes have found little or no use in industrial processes. They have provided sources of extreme value in some investigations. The spectrum of hydrogen under these conditions exhibits many lines and bands in the Schumann region. These tubes are usually of the capillary type and contain the gas at low pressures of the order of magnitude of one mm. of mercury. Obviously, in order to be useful in the extreme short-wave region, they must be provided with a fluorite window.

Lyman[1] has studied the spectra of various gases in the Schumann region. It is interesting to note that the character of the circuit and discharge influences the spectra of some gases very much. For example, argon yields no lines shorter than $190\mu\mu$ in wave-length with no capacity in the circuit. By using a disruptive discharge a considerable number of lines appear throughout the Schumann region.

PROPERTIES.

The effects of ultraviolet energy are too numerous to discuss at length in this article but a few will be noted briefly. The chemical changes in silver salts are well known and have formed the basis of the extensive developments of photography. Draper enunciated a law

for photo-chemical reactions which states that only the light absorbed is chemically active. The converse of this law—that every substance which absorbs light undergoes chemical change—apparently is not true. An aqueous solution of an inorganic salt, for example, $CuSO_4$, strongly absorbs yellow and red rays but is not altered chemically by these rays. Bichromate salts which absorb blue, violet, and ultraviolet rays are stable by themselves but in the presence of organic substances the bichromate is reduced, that is, photo-chemical action obtains.

Ultraviolet energy is in general superior to visible rays in the production of fluorescence and phosphorescence. In fact under powerful ultraviolet rays it is almost impossible to find substances which do not fluoresce to a slight degree at least. One of the most interesting experiments is found in focussing an intense ultraviolet spectrum in a horizontal position in space and bringing various substances in this plane. In this position the surfaces of solutions such as aniline dyes may be brought into the focussed spectrum. It is very interesting to note the rays which are most effective. In the case of phosphorescent materials, the regions which cause fluorescence alone may readily be distinguished from those which produce the more permanent glow. Even different colors of the resulting luminescence may be distinguished at different spectral regions of the exciting radiation. According to Sheppard, all organic bodies possessing strongly marked absorption bands in the ultraviolet, seem capable of either fluorescence in a dispersed condition or phosphorescence in a condensed condition when excited by ultraviolet energy of a proper frequency or wave-length. There have been applications of luminescent analysis to mineralogical and botanical research. This entire field of phosphorescence and fluorescence offers many opportunities for pioneer investigations.

When polished metals, such as zinc, are illuminated by ultraviolet energy they become positively charged if insulated. If negatively charged they become discharged. Under the influence of the rays, negative electrons are discharged from the metal. The breakdown voltage of an air-gap is decreased when illuminated by ultraviolet rays. Some of these phenomena may be accounted for by the ionization of the air but many metals emit electrons under certain conditions when illuminated by ultraviolet light of sufficient intensity. This latter effect is known as the photo-electric phenomenon. Even the dust particles in the air exhibit this photo-electric effect. The alkali metals are especially sensitive in this manner to visible rays as well as to ultraviolet rays. The photo-electric cell has become a valuable measuring instrument for those rays to which it is sensitive.

Ultraviolet energy is of interest from the standpoint of the permanency of coloring media because it is especially destructive in this respect.

Lithopone is darkened by these rays as is easily seen by projecting an intense ultraviolet spectrum upon a lithopone surface. By using quartz lenses and projecting the image of an arc on such a surface, the darkening was perceptible almost instantly, although it required many minutes of summer sunlight to cause the same darkening. This is a simple method of obtaining an intense concentration of ultraviolet energy which is useful in many processes and tests.

Ultraviolet energy accelerates the chlorination of natural gas in the manufacture of chloroform and hastens other processes. Blue and violet light are also effective in causing or hastening many chemical reactions.

Short-wave energy even in the near ultraviolet region is effective in changing the color of glasses especially those containing manganese. Under the influence of the radiation from the mercury arc some of these clear glasses containing manganese will assume a purplish tint after a few hours of exposure.

Ozone is readily produced in the vicinity of a powerful source of ultraviolet. It is believed by some that the solar spectrum ends at about $295\mu\mu$ on the short-wave end, due largely to ozone which absorbs maximally at $255\mu\mu$. Of course, smoke and various gases play some part.

Pure water is quite transparent to the near and middle regions but tap water is ordinarily slightly absorbing. Pidduck[2] studied very dilute solutions of salts commonly found in tap water and found distinctly different transparencies for ultraviolet although the absorption was not very great in any case.

The ionization of air by ultraviolet rays has led some to believe that the electrons or ions provide nuclei for the condensation of water vapor and thus ultraviolet energy may play a part in rainfall. Dust particles may very well serve as nuclei, and in this connection the classic experiment of artificial production

of clouds by providing various kinds of nuclei is interesting.

Ultraviolet energy is very powerful as a bactericidal agent, the disinfecting property of sunlight being one of the first principles of hygiene and sanitation. Consecutive days of rain, mist or fog permit the growth and development of pathogenic organisms.

Owing to the transparency of water to the ultraviolet rays emitted by the quartz mercury arc, the latter is in use for killing germs in water. The water is usually filtered if it contains much solid matter in order that germs may not escape death in the shadow of a suspended particle.

Some medical authorities believe that ultraviolet rays are of greater value as a curative or bactericidal agent when associated with the blue and violet rays or even with the whole spectrum.

The effect of ultraviolet energy upon animal tissues is indicated by the bronzing of the skin and especially by the destructive effect upon the membranes of the outer eye. The cornea is opaque to all rays of shorter wave-length than about $295\mu\mu$, therefore none but the near ultraviolet rays can reach the retina. But the lens is not transparent as far into the ultraviolet as the cornea. Owing to the industrial processes, such as acetylene and arc welding, which are attended by powerful ultraviolet rays, there is a demand for eye-protecting glasses. To develop such glass and to test the finished products, spectroscopy of the ultraviolet is necessary. Visual inspection cannot be depended upon for determining the satisfactoriness of eye-glasses in absorbing the ultraviolet rays.[10]

MEASUREMENT.

Although much valuable information can be obtained by qualitative experiments, ofttimes it is necessary to measure at least the relative amounts of ultraviolet energy. There are many methods available; in fact, many of the properties of ultraviolet rays may be employed in measuring the intensity of this invisible energy provided a relation between effect and intensity is established.

The photographic plate is perhaps more generally used than any other method. Relations between intensity of the radiation, exposure, and photographic action or plate density must be established for the radiation to be measured. Owing to the opacity of gelatine in the Schumann region it must be eliminated or greatly reduced in amount if this region is to be investigated photographically. Schumann adopted a special process of making silver bromide emulsions very weak in gelatine. His plates were sensitive to the short-wave region, but not to radiant energy of longer wave-lengths than $300\mu\mu$. The photographic plate is perhaps the only means used for detecting ultraviolet energy of the shortest wave-lengths.

For certain regions the electroscope has been employed because of the leakage of its charge when connected to a piece of clean zinc which is illuminated by ultraviolet energy.

The photo-electric cell is sufficiently sensitive for spectral analysis in the near and middle regions but the relation between current and intensity of radiation must be established for the cell used. When cells are made according to certain specifications this relation has been found to be linear.

If the ultraviolet energy is sufficiently intense its heating effect may be used as a basis of measurement. In such a case the bolometer, radiomicrometer, and thermopile may possibly be sufficiently sensitive under the best experimental conditions.

Owing to the large number of photo-sensitive reactions it is possible to devise various methods of measuring ultraviolet energy, at least relatively, for certain ranges of the spectrum depending upon the reaction chosen. These are too numerous to be discussed at length here.

It has been the aim to review the subject in general as it might interest the chemist. In doing this within the limits of a single article it has been impossible to dscuss many aspects and excellent researches; however, in the few references given will be found many others which will aid those who wish to pursue the subject further.

Using up Old Plumbago Crucibles

WHERE there is much crucible melting done there is certain to be an accumulation of old crucibles, and these are too often wasted. If, however, they are chipped clean from slag and metal dirt and then ground finely they will, with the addition of from 15 per cent to 20 per cent of china clay, make a first-class refractory lining for furnaces, and worked into a stiff putty or dough with water the mass will resist practically as much heat as the crucibles themselves.—*The Practical Engineer.*

[1] W. H. Mott, Amer. Electrochem. Soc., 1915. Mott and Bedford, Jour. Ind. and Eng. Chem. 8, 1016, 1029.
[2] Astrophys. Jour. 3, 1911, p. 98.

[2] Phil. Mag. 17, 1909, p. 710.

[10] Luckiesh, Trans. Illum. Eng. Soc. 9, 1914, 472.
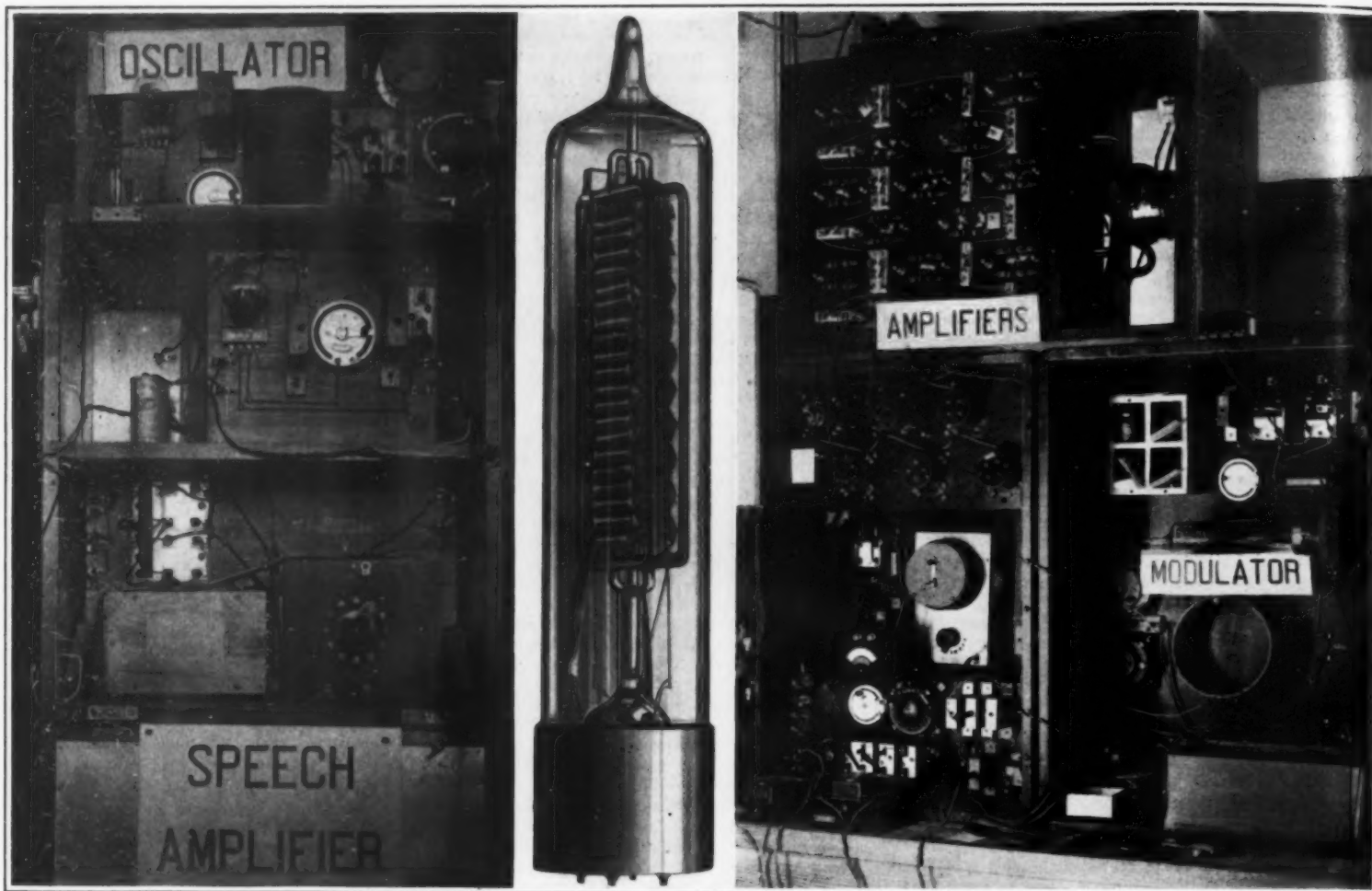
The speech amplifier (left) and modulator (right) at the Arlington Radio Experimental Station, and (center) the type of vacuum tube used in long-distance experiments

Radio Telephony—I*

The Beginnings of Long-Distance Wireless Transmission of Speech

By E. B. Craft and E. H. Colpitts

RADIO telegraphy has aroused so much popular interest that the main facts of its development to a commercial stage are known to every engineer and to many laymen. A detailed history of the growth of the art is therefore unnecessary in this paper and it is only for the sake of securing the proper point of view for a description of some recent developments in radio telephony that a short sketch of the fundamental principles involved will be presented. The work of Lodge, Marconi, Braun, Fessenden, Fleming, De Forest and many others is described in books written with this professed purpose; in fact a book of considerable dimensions is required to do justice to the historical side of the subject. These remarks are made because the present paper is concerned almost entirely with the work of the Bell Telephone System in radio telephony and little attempt is made to trace to their ultimate origins all the ideas which have entered into the building of the structure as it is at present.

Electromagnetic ether waves of "radio" frequency were first intentionally produced and studied by Hertz, who was guided by the electromagnetic equations of Maxwell, constructed twenty years earlier, which predicted electromagnetic wave propagation and the identity of light and electromagnetic radiation. Hertz succeeded in reflecting, refracting and polarizing his waves and in producing interference. The waves were generated by successive disruptive discharges of a condenser formed by two halves of an extended system, or oscillator, and were therefore damped waves occurring in trains. At each discharge a damped oscillatory current flowed to and fro along the oscillator and consequently set up outside the oscillator variable electric and magnetic states which, according to Maxwell's theory, were propagated as waves to remote regions. They were detected by means of a secondary circuit consisting of a nearly complete conducting ring broken by a minute spark gap.

This was the first radio telegraph system, and al-

though Hertz was not concerned with any immediately practical consequences of his method of producing electrical waves, others were quick to see the commercial possibilities. Passing over the very extensive body of scientific work which was started by the researches of Hertz, the next notable achievements were the discovery by Braun of the coherer for making the waves evident, and the invention by Marconi of the present form of antenna which allows the radiation of large power by long waves. These two steps undoubtedly made radio telegraphy a commercial possibility.

Because of the light which is thereby thrown upon subsequent efforts, it is worth while to examine the situation as it existed at that time. Trains of damped waves were produced by the charging of the oscillator system to a high voltage and allowing an oscillatory discharge to take place after each charge. The charges

The Montauk experimental apparatus

occurred with a frequency which produced audible sounds while the radiated waves were damped out in a rather small number of oscillations. As a result a graph of the wave amplitude would show a succession of violent and rapidly damped disturbances separated by many periods of no disturbance. This method of generation had two effects: first the average power radiated could be made large only by greatly increasing the amplitude of each separate train. This was limited by the voltage which could be allowed on the antenna and associated apparatus. Secondly, a damped wave differs so much from a simple harmonic wave that sharp tuning was impossible and the advantages known to attend its use could not be realized. These difficulties could both be overcome if a sustained wave generator of sufficient power were available; consequently this was the most important technical problem at this time and resulted finally in the development of the high frequency alternator and the arc generator.

In the meantime it had been found that bodies, such as crystals, having partial unilateral conductivity, could be used in connection with a telephone receiver to make the signals audible. In this case what was heard was the note produced by the succession of wave trains, the effect of the crystals being to rectify the received current. The rectified high frequency current varied sufficiently slowly to produce in the telephone an audible sound which continued as long as the key at the sending station was depressed. It is not necessary that the detector be completely unilateral, but only that an applied voltage shall produce a greater current when acting in one sense than when acting in the other. It was soon found that this method of reception employing a telephone receiver and rectifier or detector was far better than that of using a coherer, partly because of the greater sensitiveness, but more fundamentally because reception of an audible note by ear allows greater opportunities for discriminating against disturbances.

But with the advent of "continuous" or sustained waves, such a method could not be used without modification, because the rectified current in the telephone

receiver was either zero (when the sending key was open) or constant and equal to the average value of the rectified current when the key was closed. Such a flat-topped wave of telegraph frequency produces no audible sound in a telephone receiver except at the make and break. Two solutions of the problem thus presented were given. The first consists in breaking up the received wave into groups at such a rate that the group frequency is in the audible range. This was done by means of a commutator. The other solution, which is extremely elegant and useful, consists in superposing upon the received signal at the receiving station a locally generated wave of frequency slightly different from that of the received signal. Beats are thereby produced which are of audible frequency, and by rectifying this composite wave the current in the telephone is made to vary at any frequency desired. Since the local oscillator is not required to furnish an appreciable amount of power it may be small and may, in fact, be combined with the tuning circuit of the receiver. A more important advantage is that the signals are amplified by this "heterodyne" method of receiving.

This brief sketch brings us to the early attempts at radio telephony. It was realized at an early date that a crystal rectifier, or any similar detector, in combination with a telephone, would produce in the telephone currents whose amplitudes varied approximately as the amplitude of the received high frequency wave; consequently if the amplitude of this wave could be varied at the transmitting station in accordance with speech, radio telephony would be possible. The receiving apparatus was therefore in existence and all that was needed was a means of varying the amplitude of the transmitted wave, that is, the amplitude of the current in the transmitting antenna. Now, in wire telephony, the amplitude of a direct or alternating current is so varied by means of a microphone, and this device was tried for radio telephony, the method being to insert a microphone, or a combination of them, in some part of the antenna circuit traversed by high-frequency currents. This attempt was handicapped because of the fact that microphones, even when specially designed, cannot easily be made to carry large currents and still function properly. Their use, however, suggested that it might be possible to devise somewhat similar apparatus, and as a result there appeared numerous voice-operated resistance-varying devices. Using methods of this kind considerable success was attained; thus in 1912 Vanni succeeded in telephoning 1,000 kilometers.

FUNDAMENTAL PRINCIPLES.

In order, however, to understand the nature of the telephone problem, a short discussion is necessary to make clear what are some of the limiting factors in the transmission and reception of speech. Consider first the simplest case of the familiar wire telephone system, which will be taken as a speech-actuated microphone, a battery and an electromagnet in series. A certain current, I, flows in this series circuit and produces a pull, proportional to the square of the magnetic field strength, and consequently proportional to I^2, upon the armature. Now let the microphone be actuated and suppose its design is so good that a sinusoidal variation in air pressure produces a sinusoidal variation in the *carrier current* I. Then the result of singing a pure note of frequency $n/2\pi$ into the microphone will be to produce a current *variation* of amplitude $k\,I$, say, so that the current in the circuit is now

$$(1 + k \sin nt)\, I$$

The force on the armature will be proportional to

$$I^2 + 2 k\, I^2 \sin nt + 1/2\, k^2\, I^2 + 1/2\, k^2\, I^2 \cos 2 nt$$

This is made up of a constant part, which does not sound the telephone, a part, $2k\ I^2 \sin n\,t$, which is a perfect copy of the voice, and a harmonic, $1/2\ k^2\ I^2 \cos 2 n t$. The distortion is relatively less the smaller the quantity k, which is called the fraction of complete modulation because if $k = 1$, the amplitude of the carrier current is periodically reduced to zero. It is clear that to completely modulate the carrier current the resistance of the microphone would need to vary from zero to infinity. This is done in telegraph sending, since the key is opened, but it can only be approxi-

mated with a microphone. There are two bad results of this incomplete modulation: The full power of the system is not used since it is only the variable part which transmits signals, and any irregularities or ripples in the carrier current have a relatively greater effect the smaller the modulation, since they are themselves modulations. There was therefore an imperative need of a resistance or current-varying device which would produce variations comparable with those produced by a telegraph key.

In our first circuit it is not necessary that the carrier current be constant; thus suppose it is represented by $I \cos r\ t$, in which $r/2\ \pi$ is a high (radio) frequency
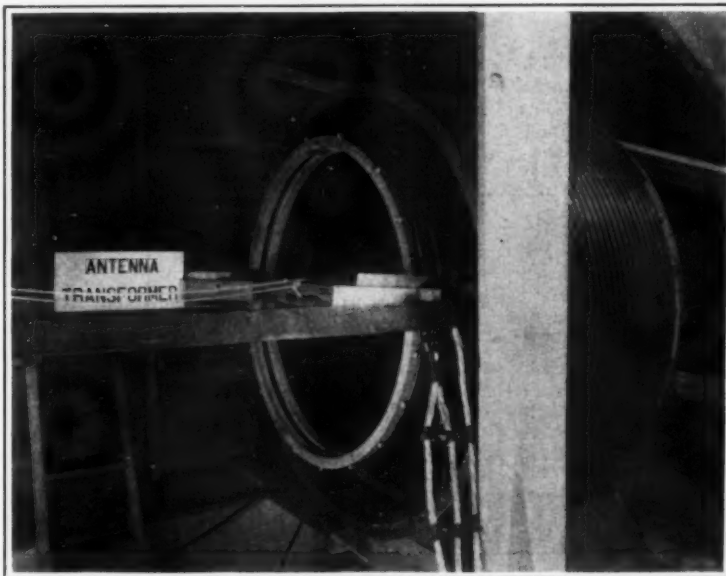
The antenna transformer at Arlington

and hence inaudible. Upon modulation the current becomes

$$(1 + \sin nt)\ I \cos rt = I \cos rt$$
$$+ 1/2\ k\ I \sin (r + n)\ t - 1/2\ kI \sin (r - n)t$$

which defines a frequency band from $r - n$ to $r + n$. Thus if speech is to be transmitted (which requires all frequencies to about 3,000) the high-frequency system must be capable of transmitting, not only the frequency $r/2\ \pi$ but a band extending 2,000 cycles on each side of this frequency. This fact imposes a limit upon the sharpness of tuning allowable in carrier-wave telephony.

The above modulated current produces in the receiver (or an e.m.f. of this type produces in a rectify-
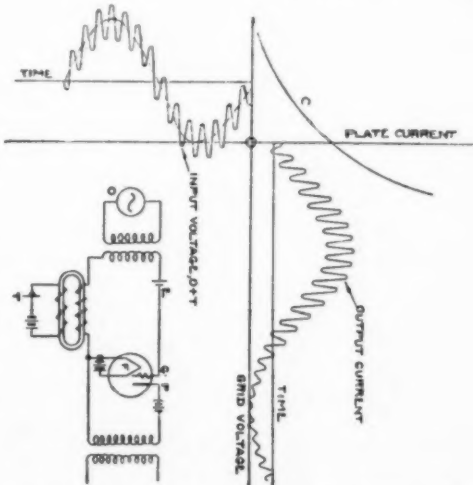

Fig. 1. Schematic representation of the modulator

ing detector) an effect roughly proportional to its square. Thus if there is impressed at the receiver another current, $A \cos r\ t$, in phase with $I \cos r\ t$, or equivalently, if the polarization of the receiver in the telephone case is made stronger, the audible frequency terms of the desired frequency will be reinforced while those of undesirable frequency will not play so prominent a part. Consequently, the received signal will be amplified with a minimum of distortion.

It is not intended to give here the theory of the modulation and detection of carrier waves, which should properly be treated in a separate paper, but this very brief sketch has shown the importance of complete modulation, the fact that radio telephony is concerned

with the transmission of a high-frequency band instead of a single high frequency, and has indicated the possibility of new methods of transmission and reception.

INTRODUCTION OF THE AUDION.

In 1906 Dr. Lee De Forest brought out a vacuum tube device which he called the "audion" and which has been described in the *A. I. E. Transactions.* This was a very sensitive detector of electric oscillations and consisted of three electrodes in an exhausted envelope. One of the electrodes could be heated to incandescence with the result that electrons were emitted by it (the Edison effect). A battery connected between this electrode, as cathode, and another as anode resulted in a convection current of electrons from one to the other. Since negative electricity only was present, current could flow in but one direction. This is so far the action of the Fleming valve which also makes use of the Edison effect, but in the audion an epoch making advance was made in that the third electrode allows us to completely *control* the strength of the electron current *without consuming appreciable energy at that electrode or in its circuit.* In other words an inappreciable amount of power applied to the third electrode, or grid, will result in large changes in power in the anode circuit. Moreover, since the electrons have no appreciable inertia, the response in the anode circuit to stimuli in the grid circuit is practically instantaneous.

Now this kind of device is exactly what is needed as a repeater in telephony. It was therefore considered by the Bell System and it was found that, provided the device could be so improved as to be able to handle the power required for wire telephony, the audion would make an ideal amplifier. In 1912 our audion development work was started with this in view, and the new device soon became a competitor of the so-called "mechanical" repeater, which it is displacing. This development of the telephone amplifier, fortunately, required a considerable amount of research in the field of high vacua and electron emission and also a rather extensive study of the electrical characteristics of thermionic tubes.

This had two results immediately applicable to radio telephony. First, an application of the early studies of amplifying systems and circuits and particularly a study of "singing" or freely oscillating repeater systems by Dr. G. A. Campbell, resulted in a successful form of thermionic oscillator, suitable for all frequencies, and second, through the work of Mr. E. H. Colpitts early in 1914, there was produced a thermionic modulation system giving approximately undistorted speech. Several related forms of modulating systems were soon after developed by van der Bijl and others.

Before describing the modulator it should be remarked that when one has a perfect amplifier and a perfect modulator, the problem of radio telephony is solved, at least theoretically, for all that is necessary is to modulate the output of an oscillator circuit and then, if necessary, amplify the modulated current. Or one may first generate oscillations of large power and modulate them by means of the amplified output of the telephone transmitter. It should also be remarked that a "perfect" modulator, *i. e.* one which may produce completely modulated undistorted carrier waves, is also a perfect detector of these waves.

Modulator. In order to understand the modulator, consider Fig. 1 in which is plotted a characteristic curve, C, of the audion. This curve shows the variation of anode, plate or output current with grid-filament or input voltage. Now let the tube be connected as shown in the circuit diagram in which two voltages are impressed simultaneously upon the grid. The first of these is due to a telephone transmitter, T, and is sufficient to vary the grid voltage from zero to the value $- E$. The second is of radio frequency and smaller than that due to the transmitter. The total voltage on the grid will then be shown, as a function of time, by the corrugated sine curve plotted vertically. The characteristic curve shows us that the resulting current in the output circuit will be represented by the variably corrugated curve extending to the right. The rapidly variable part of this curve represents a completely modulated high frequency current which may be led to an antenna or amplifier by the transformer at the right. It will be seen that the modulator acts essentially as an amplifier whose amplification is not constant but varies from zero (at the point $- E$)

to a maximum at the extreme right. The object of introducing the battery c in the grid circuit is to insure that the grid will not become positive with respect to the filament, for as long as it is negative no electrons can flow to it and there will be practically no consumption of power in the grid circuit. It is, however, sometimes desirable to allow current in the grid circuit, in which case the battery may be adjusted.

During the years 1912, 1913, 1914 a great deal of research work was carried on in connection with the development of the audion for telephony. There were many different problems involved in the manufacture of practical tubes which could handle the larger amounts of power necessary for amplifiers of telephone and radio currents. In the way of applications, laboratory apparatus was set up for amplifying telephone currents under long line conditions, a study of the detecting and rectifying properties of the tubes was made, circuits were designed for inter-connecting radio and wire telephone systems, oscillator circuits for both high and low frequencies were built, the audion was applied as a power-limiting device to protect circuits, and a number of other systems of modulation were devised.

FIRST FIELD TRIALS OF RADIO TELEPHONY.

In 1914 it was decided that the apparatus and methods developed in the laboratory were sufficiently promising to warrant an attempt at transatlantic telephony.

In order that a practical demonstration of the method might be obtained an experimental station was constructed at Montauk, L. I., and a receiving station was constructed on the roof of the Dupont Building, in Wilmington, Del. A trial was made on April 4, 1915, in the presence of a notable group of telephone and electrical executives. The transmission was, of course, one way only. These gentlemen, therefore, witnessed the operation of the transmitting equipment at Montauk on one day and then on the following day visited the receiving station at Wilmington and listened to the incoming transmission. Wire connections between Montauk and Wilmington permitted the listeners at Wilmington to report immediately what words they had heard, or, as on the second day, it permitted the speaker at Montauk to report what he had said.

Following this demonstration the range was extended from Montauk to St. Simons Island off the coast of Georgia where a receiving antenna had been erected. For the purpose of this experiment the radio receiving circuit at St. Simons was connected to a telephone circuit leading to New York. Similarly, the radio transmitting equipment at Montauk was connected to a telephone line leading from New York. The speaker at New York talked over a wire circuit to Montauk, by wireless to St. Simons and then by wire to a listener in New York.

The method which was used in transmission was essentially that which was followed in later experiments when the Navy station at Arlington was used as a transmitting station. Prior to this time the inability of inventors to modulate large amounts of power in such a manner that the modulated current, when detected at the receiving station, could be obtained essentially free from distortion, had proven a serious limitation on the increase of range of transmission. It had been shown, however, that this limitation could be overcome by the use of the audion amplifier and modulator. The general method proposed, therefore, and the method finally developed was as follows. A small current of high-frequency was to be generated by means of a vacuum tube oscillator. This high-frequency current was to be modulated, essentially completely, by the voice current from the telephone transmitter. The resulting modulated current was to be amplified, or successively amplified, by distortionless amplifiers, of the vacuum tube type, until the energy which it represented was sufficient for transmission from an antenna over the desired distance.

For the production of a sustained high-frequency current a vacuum tube was used. With such a tube, provided its input and output circuits are coupled together and one of them contains a tuned circuit, the operation is one of successively amplifying its own output. This successive amplification will result after a moment in the development of a steady state of oscillation in which there is a definite maximum of output current. This maximum amplitude of the generated alternating current depends for its value upon the characteristics of the tube itself. An oscillation generator for producing alternating current is shown in Fig. 2. Power may be obtained from it by coupling loosely to the inductance of its circuit another inductance which in turn is connected to the point where this power is to be utilized.

As noted above, the study of the vacuum tube had

also indicated that although it was possible to use the tube as a distortionless amplifier, it was also possible to adjust its voltages and the impedances to which it was connected so as to produce a distortion of the input current in a manner suitable for the purposes of radio telephony. Under such conditions the output of the tube contains a component which is proportional to the product of such voltages as may be simultaneously impressed upon its input or grid-filament circuit. If one of these inputs is obtained from the oscillation generator just described and the other from a telephone transmitter, it is then possible to obtain an output which varies harmonically with the frequency of the oscillation generator, and also varies harmonically in amplitude with the frequency of the voice current impressed by the transmitter.

A vacuum tube, properly designed for the impedances between which it was to be connected and properly adjusted so as to emphasize the modulator characteristics, was used as a modulator in the system of transmission which was formally demonstrated at Montauk. To its
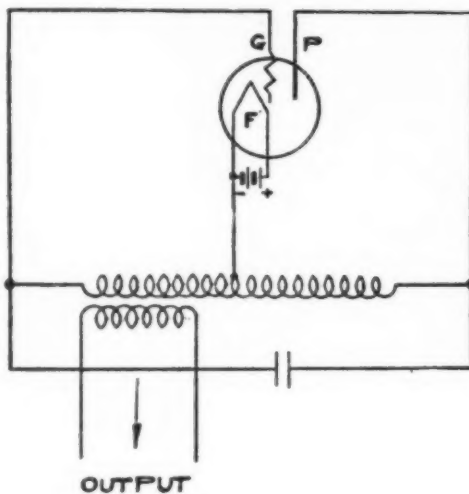

Fig. 2. Scheme for the oscillation generator

input was coupled inductively the tuned circuit of the oscillation generator and also telephone transmitter circuit containing a local battery.

In order to obtain a sufficient amount of energy for transmission over appreciable distances, it is necessary to amplify the energy output of the modulator before impressing it upon the antenna. In case considerable amplification is desired it may be obtained by impressing the voltage from the modulator upon an amplifying system formed by two amplifiers in tandem. It was also realized that amplifiers might be worked in parallel, that is, with their input circuits connected in parallel and with their output circuits connected in parallel, without introducing disturbing interactions, provided that certain precautions are taken. The method of amplification adopted for the Montauk tests and later used for the Arlington experiment was therefore a system of two stages of amplification. At Montauk the first stage was obtained by a single tube and the second stage by a number of tubes in parallel. On p. 244 is shown a view of the experimental apparatus used at Montauk. On the left in the foreground is a rack containing the amplifiers of the second stage. On the right, immediately above the battery racks, are four boxes containing the other radio apparatus. The upper right-hand box contains the oscillation generator. The box immediately below this holds the modulator and its associated apparatus; the upper box on the left contains the vacuum tube of the first stage of amplification; and the box below it has a tuned circuit and certain controlling resistances which enter into the transmission system.

THE ARLINGTON-DARIEN EXPERIMENT.

The tests from Montauk to Wilmington and to St. Simons Island were so successful that it appeared practicable to carry the method to its logical conclusion and to extend the range of radio telephony to much greater distances. For this purpose experiments were undertaken in conjunction with the Navy Department. For the initial steps in making such arrangements and for assistance throughout the experiments, we are indebted and distinctly grateful to Admiral R. S. Griffin, Engineer in Chief, U. S. Navy, Captain now Admiral W. H. G. Bullard, Superintendent of the Radio Service, and to Commander now Captain Hepburn and Lieutenant now Commander S. C. Hooper of the Bureau of Steam Engineering, U. S. N.

For the purpose of these experiments a small oper-

ating house was constructed beside the main operating building of the Navy Wireless Station at Arlington, Va. An antenna switch was provided so that the antenna might be connected to the Western Electric equipment in this experimental station. Captain Bullard also arranged for observers from the Western Electric Company to be present at the Navy stations at Darien, San Diego and Mare Island. The necessary apparatus was installed in the early summer of 1915 and preliminary experiments were started at once. On August 27th successful transmission was obtained to Darien on the Isthmus and was received by Mr. R. H. Wilson of the Western Electric Company and by Lieutenant R. S. Crenshaw of the Navy.

On this day Colonel Reber, Lieutenant Bryant of Captain Bullard's office and Mr. G. H. Clark, Radio Expert of the Bureau of Steam Engineering, had been asked to speak from Arlington in the hope that communication would be established with Darien. Immediately prior to the time these gentlemen spoke, two selections were played on a phonograph placed in front of the telephone transmitter. These were correctly recognized by Wilson and Lieutenant Crenshaw. Each of the visitors then spoke for a minute or two. The voices of the speakers were not familiar to the observers at Darien. Wilson, however, recognized the change in voice caused by a change in speaker and received correctly several phases and some scattered words. These words were also verified by Lieutenant Crenshaw. A report of these results was sent immediately from Darien by Navy code to Arlington and was compared by the speakers with their records of their spoken words.

The method of transmission was essentially that described above in connection with the Montauk experiment. The transmitters used in these tests were of the ordinary commercial type, or of a type which was then in a stage of development and which it was thought might reproduce more exactly some of the higher harmonics of the voice. A phonograph was also used for the transmission of music. The output of the transmitter was amplified in a speech amplifier of the audion type, which is shown on p. 244. The high-frequency oscillator is shown in this figure above the amplifier where the tuning condensers and the coil for coupling to the inductance are plainly visible. The output of this speech amplifier and of the high-frequency oscillator were both impressed upon a modulator of the vacuum tube type, shown likewise. The voltage of this amplifier was not, however, high enough for the main amplifying tubes, and it was stepped up by an intermediate group of amplifiers, of which six as a rule were used, which are shown at the left of the figure. The modulator output thus amplified was impressed upon a number of power tubes in parallel and then upon the antenna transformer shown on p. 245. The type of power tube is illustrated on p. 244. The amplifier tubes preceding the power tube and the modulator were also of the same form, but were of different constants, properly adapted to their purposes.

The current by which the filaments were heated was supplied by a local power company and brought in by underground cable to the operating station. Alternating current was used for heating the filament and any possibility of the superposition of a 60 or 120 cycle note, due to the frequency of this current, was eliminated by a special scheme of connections. Between the plate and the filament of the power tube a constant voltage of about 500 volts was impressed. It was obtained from one of the motor generators used by the Navy in operating the large Poulsen arc, with which they were then transmitting to Darien and other remote points. A large amount of energy, of course had to be dissipated in such an equipment because of the energy supplied to the filaments, and a blower was installed for this purpose, with a switchboard for operating remotely the motor generator set in the main station of the Navy, for controlling the alternating current supplied to the filament, for operating the blower, and for metering the currents used for lighting the plant and for similar purposes.

The method of reception was varied from time to time as it was still in process of development. In some cases an amplifier for the high-frequency currents was introduced between the detector and the tuned circuit which was coupled to the antenna. In some cases a low-frequency amplifier was inserted between the detector and the receivers. In some of the later experiments a feed back circuit was used for the detector so that the detector tube itself acted as an oscillation generator as well as a detector. In that case the frequency of the oscillations was adjusted to be the same as those of the oscillation generator at the transmitting station.

[TO BE CONTINUED.]

Molecular Association and Chemical Combination[*]

Are Cohesion and Chemical Affinity Forces of Similar Nature?

By Felix Michaud, Sc. D., Fellow of the University of Paris

DOES a definite relationship exist between molecular associations and chemical activity? Can the tendency which a substance possesses to combine with itself be likened to its tendency to combine with other substances? Or in other words, to speak the language of the atomist, do the attractions which manifest themselves as existing between identical molecules constitute an index for these molecules of an attractive power which is, perhaps, independent of the molecule attracted?

This question has been put by many scientists. Some of them have answered it in the affirmative and have suggested, following Kékulé, what are called "associationists" theories of chemical activity. Among these may be mentioned H. E. Armstrong, Engler and Ph. A. Guye.

A great many substances in fact which are revealed by tryometry or ebulliometry as being "associated" have a tendency to combine with each other. According to Kremann, the benzenic compounds in the ortho position are less apt to form additional compounds than are the meta and para derivatives. They also show less tendency to become associated, but no general law has as yet been formulated. The laws which one might be tempted to propose are subject to numerous exceptions. Turner, who studied the question extensively, came to the conclusion that the forces to which molecular associations are due either have a different origin from the forces of chemical affinity or else, if they be of the same origin, act in a different manner.

The attempt to frame an atomist theory would be vain. We might account for the facts doubtless if sufficiently aided by new hypotheses; but a theory thus constructed, even supposing it could be formulated without involving contradiction, would inevitably be very complicated and probably impossible to apply.

It must be recognized, in fact, that the results obtained in Physical Chemistry by the theory of Atomism scarcely encourage continued pursuit along this line. After the rapid and brilliant successes of the theory of ions it is now in a period of decline. As facts obtained by experiment become multiplied, and as measurements become more exact, difficulties appear which are at times almost insurmountable. We need only cite the influence of neutral salts upon the hydrolyzing or dissolving action of acids. If the action of the acid is due to hydrogen cations the presence of a neutral salt having the same anion should diminish the dissociation of the acid and consequently its activity, but this is not the case; it is just the opposite which happens. Actual experiment yields results which are absolutely opposite to that which the theory of ions would indicate. It has been necessary to add to the original theory various arbitrary and conjectural complications, in regard to which, moreover, investigators are far from being in accord (Arrhenius, Snethlage, Armstrong).

Let us abandon, therefore, the uncertain ground of Atomism and go back to the *terra firma* of Energetics.

I. THE THEORY OF SYSTEMS IN EQUILIBRIUM.

We shall see, in the first place, that it is possible by means of reasoning based upon the principles of Thermodynamics to establish the following general law with regard to systems in equilibrium; *A constituent taken in the gaseous state and in a definite molecular condition has but a single equilibrium pressure with respect to a system containing this constituent.*

To demonstrate this let us consider a system constituted by a certain number of homogenous areas (called "phases" in the terminology of the physical chemists) in equilibrium with each other.

Let us replace one element of the wall enveloping the system by a semi-permeable partition which allows only one of the components of the system to pass into the state of gas and into a definite molecular condition[1]. This partition constitutes the bottom of a cylinder within which a piston moves back and forth. To prevent the component from making its escape through the semipermeable wall it is necessary to exert upon the piston a pressure which we will indicate by P. In the same way we will arrange in another area of the wall of the system—for example, one in contact

with another phase—a second semi-permeable partition of identical nature with the first and also forming a cylinder with a piston. In the same way we must exert upon this piston a pressure P' to prevent the component from escaping through this new exit.

I maintain that P is equal to P'. If this were not true, in fact, we should be able to obtain a so-called perpetual motion of the second species, since the system would then emit gas under certain pressure and recover it under a lesser pressure. This action would be repeated indefinitely, equilibrium being re-established spontaneously between the phases, and the system would always remain identically the same.

Thus as we see the principles of Thermodynamics require that each component of a system shall have under a given molecular condition only a single equilibrium pressure with respect to the system under consideration.

The preceding theory established in the special case of gaseous pressure is more generalized, however; it can be demonstrated quite as readily in the case of semi-permeable walls which allow the component to pass into another physical state (liquid or solid). The corresponding equilibrium pressures are then what we propose to call the *liquid and solid pressures* of the component[2]. Finally, when we suppose the wall permeable to the substance and impermeable to entropy, the corresponding equilibrium pressure will measure, as we have seen[2], the chemical potential, and we here recur to the well known theory according to which the potential of each constituent is the same in two phases which are in equilibrium.

II. THE EXCEPTION OF SOLID COMPOUNDS.

The example of the hydrates proves that when a compound in the solid state is in the presence of the vapor of one of its components, there is only a single equilibrium pressure. Thus, to cite a single fact among many others of an analogous nature, the hydrate of sulphuric acid of the formula $SO_4H_2.2H_2O$ remains in equilibrium at 0° C. with the vapor of water disengaged by a solution of 80 per cent. sulphuric acid, but is still stable at the same temperature in the presence of vapor proceeding from an 88 per cent. solution of acid.

Let us suppose that the hydrate occupies the bottom of a U tube and that each of the two branches contains, separated in this manner by the solid phase, the two solutions in contact with which the hydrate can exist in equilibrium. These two solutions have not the same vapor pressure; hence they would not be in equilibrium with each other. Each of them, however, is in equilibrium with the solid phase. Thus we see that two phases, each of which is separately in equilibrium with a third phase are not necessarily in equilibrium with each other.

These exceptions to the rule demonstrated above are readily explained, on the whole, by the existence in crystalline solid bodies of an "energy of form" which prevents diffusion taking place through them and permits the compound to remain in equilibrium with the vapor of one of its components for any pressure values whatever, always provided, of course, that these values remain comprised between certain given limits. This observation can readily be made general in the case of *liquid and solid pressures* and in the case of chemical potentials. For these latter in particular it may be said that in a given compound in the solid state the potential of each of the components has no definite value but remains comprised between two extreme possible values.

Experience shows, however, that when the temperature rises the limiting values of the equilibrium pressures of the components tend to approach each other; in other words, this "interval of stability of the solid compound," as it may be termed, tends to diminish. For a given temperature, which coincides in dissociated bodies with the fusion point, this interval becomes nil. We are then dealing no longer with a combination but with a mixture, in which the components have equilibrium pressures and definite potentials which are no longer uncertain in character.

It is not necessary to believe that this "exception of solid compounds" is contrary to the principles of Thermodynamics. Let us return, for instance, to the case of the U tube just now considered. We might borrow water vapor from one branch and restore it to the

other. The pressures being different we should either have given or received work done. But the system would have changed. The solid hydrate, whose composition is intermediate between that of the two solutions, either melts or crystallizes in such a manner as to keep the compositions of the two liquid phases constants. If we remove water vapor from the most dilute solution and replace it in the most concentrated solution, the hydrate will crystallize. It will melt, on the contrary, if the transfer is made inversely.

This question of solid phases is very delicate in nature and deserves much more extensive discussion. We shall confine ourselves here to what has just been said and will sum it up as follows in order to make use of the principles here stated further on:

1. At a given temperature the pressure of the vapor of equilibrium of each of the constituents of a dissociated solid compound is comprised between two definite limiting values;

2. The vapor pressure of one of the components cannot be greater than its maximum limiting value without causing the solid phase constituted by the compound to disappear.

III. THE RELATION BETWEEN THE STABILITY OF A COMPOUND AND THE DEGREE OF MOLECULAR ASSOCIATION OF ITS COMPONENTS.

In the preceding remarks we have supposed an adaptation to the system of semi-permeable walls allowing one component to pass into the gaseous state and into a definite molecular state. Let us now imagine that we are again utilizing two walls permeable still to the same component in the gaseous state, but that while one of them allows it to pass in a certain molecular condition, the other allows it to pass only in a different molecular condition. For example, that one of the walls is permeable only to simple molecules and the other only to double molecules.

The principles of Thermodynamics will then no longer demand the equality of the two equilibrium pressures, but they will require a definite relation between these two pressures. We can demonstrate that the equilibrium pressure p of the simple molecules is related, the temperature remaining constant, to the equilibrium pressure P of the double molecule in the following ratio: $\frac{P_2}{P} =$ constant. This is the law called the action of the mass.

Upon taking the differential logarithm of this equation we see that the relative variations of p and P are as one is to two.

If the second wall instead of allowing double molecules to pass alowed triple molecules to pass, the exponent and the factor 2 would be replaced by the exponent and the factor 3, etc.

We see then, on the one hand, that a very great pressure of associated molecules can balance a very small pressure of simple molecules; and on the other hand that the relative variations of the equilibrium pressures of two different molecular states are in the ratio of the degrees of molecular association.

IV. A CASE OF A MONO-ATOMIC COMPONENT.

A very curious application of the results set forth above is that which relates to the case in which the component under consideration is a simple mono-atomic body in the free state. In this case when it combines it can do nothing but remain mono-atomic or associate with itself. The vapor of the compound will then contain, supposing the dissociation to be at the point of beginning, some of the component in the same molecular state as in the free state or in a more condensed molecular state.

We shall see that we have here an important factor of instability, and that the result of it is that the component, unless it possess a very slight degree of volatility, will find it almost impossible to form dissociated compounds.

Let us consider in fact a mono-atomic body whose critical point is very low, *i. e.*, whose ordinary condition is gaseous. The relative variations of its pressure are capable in this case of being very great. Let us suppose that this gas is capable of forming dissociated compounds, and let us place it in the presence of one of these compounds. According to what we have just observed the relative variation of partial pressure of the gas in the vapor of the compound should be at least equal to the relative variation of the pressure of the free gas. The state of dissociation


[*]Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from Révue Général des Sciences (Paris).

[1]The utilization in the above article of the conception of semi-permeable walls which allow one component to pass in any given physical or molecular condition whatever can be easily justified. Vid. F. Méchaud: Contribution to the Study of Mixtures (Thesis, Paris, 1916, Gauthier-Villars).

[2]*Loc. Cit.*, p. 26.

[3]Révue Général des Sciences. Vol XXVIII, p. 604, Nov. 15, 1917.
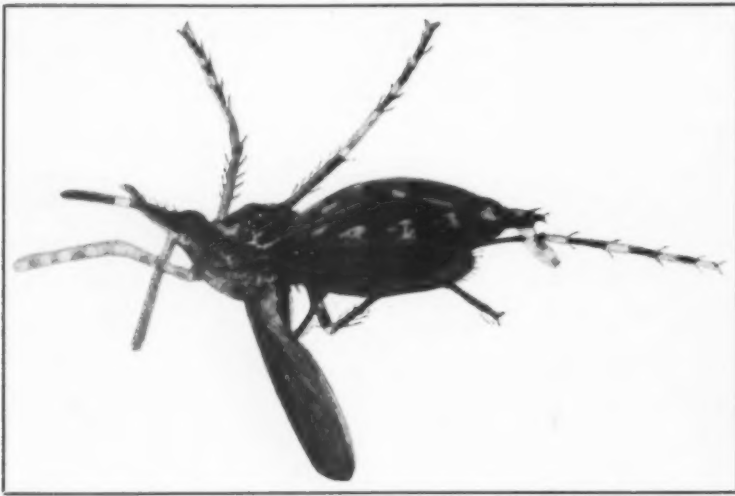
Mosquito at rest during digestion of a heavy meal
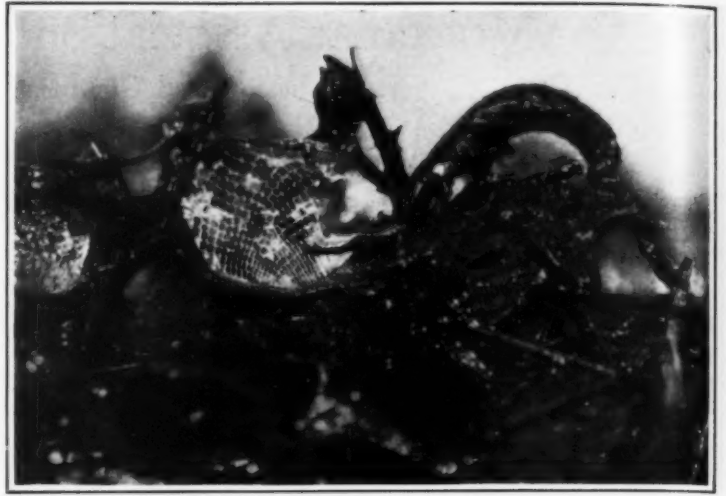
Young of caddis fly, with its fishing net

Familiar Insects Through the Camera
Incidents in the Lives of Our Tiny Neighbors of Forest and Field

Photographs Copyright by Brown and Dawson

THERE is always something to surprise us and intrigue our interest in an enlarged photograph or a photo-micrograph of the common insects that surround us in our daily life. The creatures look so familiar when seen with the eyes of dwarfs, and yet so strange, that we can never resist the fascination of pictures of the sort shown on this page, and on our cover for the week.

Our good old friend the mosquito is shown here attending to his digestive duties after a hearty meal—a meal, by the way, that was made at the expense of the photographer, busy photographing insects of a more pleasing sort. Like any well behaved snake, the "merrywings," as they call him in the worst-infested regions of the Long Island shore, has to have quiet and leisure to enable him to work over for his own use the nutritive elements that enter his alimentary passages; and he is here shown in the act, in what looks like an impossible position upon the window-pane.

A less familiar and more attractive sight is presented by the mosquito's neighbor on the page, the young of the caddis fly. At the stage of its life here shown, this curious worm-like creature inhabits the brook beds and small river bottoms, where it constructs a delicate and very beautiful net of silken threads. This web is funnel-shaped, and is so anchored in the current that quantities of the flotsam and jetsam of its small marine world is caught up from the passing water. The fisherman lies in wait in his little parlor at the end of the funnel, like the proverbial spider, and selects what food it desires from the mass thus caught.

Pictures of the ant in war and in peace we shall always have with us. In the middle of the page we


A group of dead ants after a battle

show one of the former category, and on our cover one of the latter. The picture on this page shows the aftermath of one of the ferocious battles in which these highly "civilized" creatures engage periodically. The particular conflict in question took place in a work shop, lasting all night and being witnessed by several persons. Hundreds of the combatants were slain, and it is a group of the corpses that are illustrated, just as they were picked up after the armistice, each one linked to its antagonist. Doubtless the survivors will amuse themselves, in the interval between this and the next encounter, in elaborate projects to make this indiscriminate slaughter unnecessary.

As evidence that the ant does not spend all his time in killing his fellows, however, we have the simple pastoral scene on the front page. Here we have the ants milking their cattle. The grotesque little bugs clustered about the plant stem are aphids or plant lice. These tiny creatures live by sucking the sap from the plants that form their abiding place. But the ants have learned that the aphids give out an excrement in the form of a sweetish liquid of high nutritive value. So the ants have domesticated the aphis; treating them with great respect, protecting them, herding them together, and finally living upon the supply of honey-sap that they produce. In the picture we have two large carpenter ants visiting their flock.

Some years ago there was a great furor through the East—and for all we know, through the rest of the country as well—over the "kissing bug" and his imagined deadly effects. The legend, as we recall the version current in our neighborhood, was that the insect in question would sew the lips of a human together, much as the darning-needle is often reputed to sew down the flap of the human ear. After that we

Assassin bug, or kissing bug, laying its bottle-
shaped eggs on a stout twig
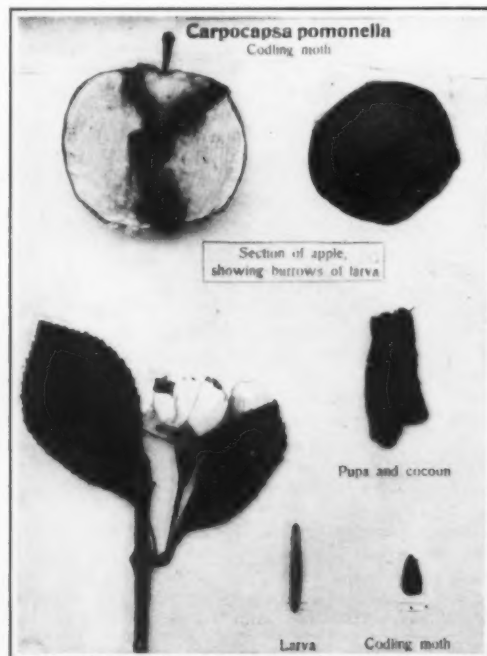
Stages in the life of the codling moth

The poisonous stars which protect the Io caterpillar
from insect-eaters

A curious case of protective coloring

A caterpillar that resembles a leaf bud

The tree cricket in the act of singing

do not know what was supposed to happen to his unfortunate victim—but in any event, here is the insect, under his rightful name of assassin bug. The story built up about him at least the basis in fact that the creature has a long, sharp beak, quite capable of piercing the skin. The assassin is predatory in character, feeding upon smaller insects. The eggs resemble little wide-mouthed bottles, and are laid in clusters upon twigs in early September. These lie dormant over winter and hatch in the spring. The insect in the photograph is in the act of depositing an egg, the tip of which can be seen emerging from the ovipositor. It will be seen that this particular Mrs. Assassin has progressed well with her egg laying, as she has quite a comfortable group of potential offspring in place on her twig.

To give the collection of pictures a proper museum flavor, we include the one showing the little nuisance that makes some apples bad eating. It is not necessary to name its formidable name here, since that appears once in the cut; we may give thanks that the scientists have permitted so simple an English appellation as codling moth to be attached to it. The several portions of the group at the bottom of the page, in the middle, show the life history of this insect sufficiently well to make elaboration superfluous.

Another kind of moth is the one responsible for the last picture on the page. We have here a highly magnified section of the Io caterpillar, which will later transform itself into the Io moth. The caterpillar is magnificently protected from its enemies by eight formidable rows of highly poisonous spines, the slightest scratch from which is sufficient to cause a decided sting in the human, followed by itching and prolonged irritation. Needless to say, the effects upon the smaller creatures who would normally art as the agents of evolution in helping to exterminate the species are correspondingly more severe, and the Io is quite immune to attack from birds and other insects. The photograph here shows the so-called poison stars, the groups of spine by means of which the Io caterpillar makes itself feared among its neighbors.

All members of the caterpillar-butterfly community are not so unpleasant in appearance as this one. Of course, we expect a caterpillar to be hideous and a butterfly or moth to be more or less beautiful according to its species, so perhaps the comparison is hardly a fair one. In any event, we have here the scales or shingles of a butterfly's wings. These members, in all species, are made up of thousands of little shingles overlapping one another for all the world like the

article of building construction from which they take their name. In fact, the powder that one finds upon one's fingers after handling a butterfly consists in reality of hundreds of these tiny members which have become detached from their delicate moorings. The enlarged photograph, which is everything but a photomicrograph, gives some idea of the minute dimensions of these scales.

All of us have seen the extraordinary animal who is pictured beside the butterfly wing. Walking stick is the name under which it usually goes, though some captious critics prefer to call it the thread-legged bug. Perhaps the greatest mystery about it is what it eats—what it can find to eat that is suited to its absurd form. The answer will be surprising to many of us; for he actually lives upon flies and small bees which it steals from the webs of its spider neighbors. It holds these doubly unfortunate victims in its spiked
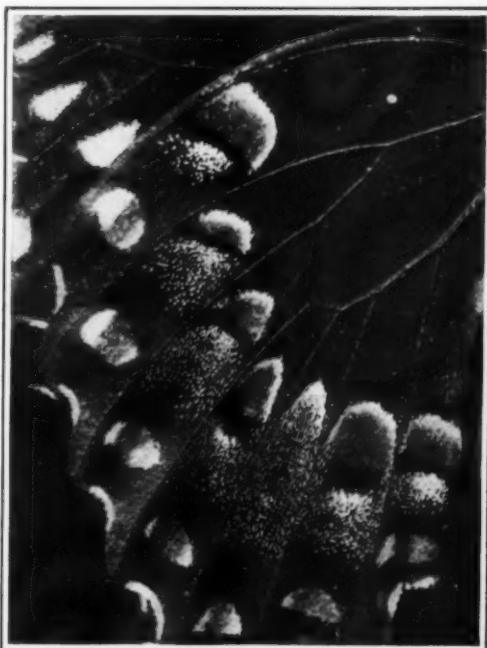

The shingles of a butterfly's wing

The walking stick on a pilgrimage

and modified fore-legs, while with its long, sharp beak it drains them of the juices which support the combustion of life, and then discards the husk. Its feet are specialized to suit its peculiar habit of securing its food; it is able to walk in a cobweb, much as the spider does, without danger of becoming entangled. It once possessed wings, but has lost them through disuse. It is to be found mainly in old sheds and buildings, in spite of the camouflage of its form, apparently intended to enable it to elude observation among twigs and grasses.

A creature that does not thus allow its natural protective coloring to be wasted on the desert air is shown above, at the left. This is a caterpillar again, resting upon a leaf, and looking for all the world like a fragment of bird excreta. Again, in the center, we have a somewhat different case of mimicry—a case where the form is the determining factor in the deceit, rather

than the color. This is still a slug caterpillar, a small one, and one that will transform, when its time comes, into a small and inconspicuous moth. For the present, too, it is inconspicuous, but through being conspicuous. Its color is leaf green, with a dash of rusty red near the head, which is down in the picture. No one can help seeing it, on the stalk which it inhabits; but hardly any one will suppose, upon glancing at it, that it is anything other than a tiny leafbud—perhaps a trifle swollen, but none the less plainly a bud.

Finally we have a friend of vacation days about whom all have heard, but who will doubtless be a stranger to the eyes of some. This is the tree cricket, and the camera has caught it in the act of singing its song. The city dweller who has had his first night in the country made hideous by this creature and others of the same general character will be well prepared to credit the statement that his note is repeated "incessantly" at a rate of about 120 times per minute. However, things might be worse, because we are assured that this species possesses a sweet flute-like tone quite different from the strident note of the ordinary hearth cricket. The insect pictured is a delicate green in color, with long, hair-like antennae. The sound is produced, as most of us know, by rubbing the wing covers together when held perpendicularly to the body. It might seem that at different individuals it would sing in different keys, according to individual predilection; but we are told that this is not the case, that the tree cricket vibrates only to the pitch of D-flat.

The Ductility of Platinum

THE American Museum of Natural History has recently issued a bulletin giving many interesting facts relating to platinum, one of the most striking of which relates to its ductility. The marvelous ductility of platinum may be conceived when we consider that out of a single troy ounce of the metal it would be possible to make an almost infinitely slender wire that would reach from Santiago, Chili, across the continent to Rio de Janeiro, a distance of about 1,800 miles. To draw out platinum into so exceedingly fine a wire it is covered with a thin layer of gold. This new wire is drawn to the thinness of the former one and the gold is dissolved.

A small section of this second wire is then given a coating of gold, redrawn, and the gold covering dissolved. After this process has been repeated several times, the wire finally obtained is still intact, but virtually invisible.

The New American Merchant Marine—II

A Plan for the Ownership and Operation of the Vessels Built for the Government by the U. S. Shipping Board

By Edward N. Hurley, Chairman of the Board

[CONCLUDED FROM SCIENTIFIC AMERICAN SUPPLEMENT No. 2258, PAGE 227, FOR APRIL 12, 1919]

THIS fund to be drawn from the sources previously indicated, should be used to relieve such financial difficulties as may be encountered in the development of an adequate and well-balanced American Merchant Marine. For instance:

It is foreseen that a number of trade routes important to the immediate or future welfare of American commerce must be established and developed. Some of these routes may not yield steamship operating profits until their existence shall have attracted an increased volume or better balance of trade. Revenue derived from the carriage of mail, and possible fees for the training of seamen and cadet-officers, may partly compensate losses incurred on these routes. Still, in cases where the Government sells a ship upon condition that it be operated in a route which may not prove profitable at once, it will be necessary to provide for the payment of defaulted interest from the Merchant Marine Development Fund, in the discretion of the Shipping Board or other Government agency, upon recommendation of the Board of Government Directors, until such time as the route may begin to yield profit. When the ships in the route earn their annual interest rate and a profit, one-half the profit earned each year should be paid into the Merchant Marine Development Fund until all moneys drawn from the fund on account of the vessel in question shall have been replaced. The other half should go annually to the steamship stockholders.

Such vessels cruising in routes which fail to prove susceptible of profitable development and which do not serve any purpose of the Government of the United States, may be transferred by the Government to other routes. However, should the Government become convinced that any vessel has failed to make expenses solely or chiefly because of incapable management, it may foreclose its mortgage on that vessel.

On the basis of one billion dollars' worth of ships, the Merchant Marine Development Fund would be fourteen million dollars. This amount, investigation convinces me, would be more than sufficient to care for all deficiencies likely to develop during this period.

Until sold under the terms just stated, all vessels should remain the property of, and should be operated by, the Government of the United States.

CONTROL OF RATES.

Taking up these points seriatim, I wish to enlarge and comment upon them as follows:

In order to make sure that the American Merchant Marine will be operated with due regard for the interests of American industry and commerce, it is necessary to exercise control over the maximum freight rates which may be charged in regular trade routes.

Sections 16 and 17 of the Act approved September 7, 1916, provide remedies for unjust discrimination by American shipowners against any American shipper or port, and they also forbid the collection by common carriers in foreign commerce of any rate unjustly prejudicial to American exporters as compared with foreign exporters. Section 18 of the same act authorizes the fixation of maximum freight rates charged by common carriers by water in interstate commerce.

There remains to be provided means for preventing the impartial imposition of unjustly high rates upon all commerce moving into or out of the United States. This is manifestly beyond the power of legislation at the moment, and it is proposed to secure such control by agreement inserted in the bill of sale under which the ships are released, and by making such control a condition of participating in the benefit of the Merchant Marine Development Fund.

THE SELLING PRICE OF THE SHIPS.

It has been recommended that the ships be sold at prices which fairly reflect the world market for similar tonnage. If a higher price were fixed the purchaser would not be able to compete with the ships of other nations carried at a lower rate. If a lower price were fixed Government property would be sacrificed, and at the same time a blow would be struck the American shipbuilding industry by the low value at which ships in operation would be carried on the operator's books. The sale of the vessels at the world market price would be fair to operator and builder alike. Also, it would automatically fix the write-off which must be made on account of the excessive and necessary war-cost of the ships.

*An address before the Marine League in New York.

TERMS OF SALE.

A substantial payment should be required upon the delivery of the ship. The best interests of the Government, the operator, and the American Merchant Marine demand that this initial payment should be at least 25 per cent. of the price of the vessel. Subsequent payment should be made as follows:

Beginning of the first	year (initial payment)	25%
" " " second	"	10%
" " " third	"	9%
" " " fourth	"	8%
" " " fifth	"	8%
" " " sixth	"	8%
" " " seventh	"	8%
" " " eighth	"	8%
" " " ninth	"	8%
" " " tenth	"	8%

This schedule provides for the payment of 60 per cent. of the purchase price in the first five years, and 40 per cent. during the last five years. Such payments would establish the purchasing companies on a firm basis, and would serve to discourage any purchaser who might contemplate reaping large profits during the first two or three years, with a mental reservation to retire as soon as present high freight rates decline and profits cease to be abnormal. At the same time these terms are not so severe as to call for any financial assistance beyond that which usually is accorded reasonably well-managed commercial enterprises in this country.

It is important that all ships be sold on these terms, and on no others. If we were to deviate from this principle we would place the big, powerful and experienced operator in a position of such great advantages that new blood and brains hardly would dare venture into the business. The American Merchant Marine needs enterprising new companies, financially able to begin operations only upon a small scale, but determined to grow to great size and prosperity by dint of perseverance and grit. This is the way new industries on shore have become mammoth in less than a generation, and it is largely upon the application of the same genius and methods in this new field that we may safely rely to enable our inexperienced people to drive their way to success upon the sea.

INSURANCE.

Simultaneously with the purchase of a vessel, the purchaser should be required to provide hull and machinery insurance for his equity with an American Marine Insurance Company. As additional payments are made, the equity they represent should be insured in the same manner, until a hundred per cent. of the hull and machinery insurance has passed into the hands of private American insurance companies. This arrangement would achieve the double purpose of relieving the Government of the insurance risks which the exigencies of war have compelled it to assume, and of making possible the development of an American marine insurance market capable of carrying insurance on all the vessels under the American flag. The history of our Merchant Marine shows conclusively that it is essential for American shipowners to insure their ships with American marine insurance companies. An American marine insurance market is as vital a necessity to an American Merchant Marine as is American capital to the steamship companies which constitute it.

The part of the equity in each ship which is covered by the Government's mortgage should continue to be insured in the Government's funds, as at present. As the payments progress, however, this equity will decrease, until at the end of ten years, the Government will have no more need of carrying any insurance. Additional legislation will be needed to enable the Government to carry this insurance beyond the emergency period now authorized by law.

THE MERCHANT MARINE DEVELOPMENT FUND.

It has been indicated that this plan contemplates the setting aside of certain moneys representing the difference between the customary commercial charges for interest and insurance and the rates at which the Government, in virtue of its peculiar position, is enabled to charge. In the matter of interest, it has been shown that this difference would be 1 per cent., which represents the advantage over the customary commercial rate of 5 per cent. which the Government can concede without loss in view of the fact that 4 per cent.

is the rate which approximates the interest the Government is accustomed to pay for money it borrows. In the matter of insurance, the experience of the war period indicates that the Government can safely carry vessel insurance at more than 1 per cent. below the commercial market rate.

As heretofore stated, the money derived from these two sources will amount to $14,000,000 the first year. Expert shipping men have carefully computed that this sum will be double the amount needed to meet any contingency likely to arise. This money should be paid into the hands of the Shipping Board, or other designated Government agency, as trustee, to be used as may be necessary for the development of the American Merchant Marine.

A good idea of the resources which this plan provides for financing the development of the American Merchant Marine can be gathered from the following table. It is assumed that the money will be placed in an approved depository where it will draw interest at 2 per cent., compounded semi-annually. Remembering that any disbursements which may be made during the first few years will be returned during the last few years, it will be seen that the size of the fund for the ten-year period will be $83,533,170.70.

TOTAL ACCRUALS TO MERCHANT MARINE DEVELOPMENT FUND DURING TEN-YEAR PERIOD.

Period.	Deposits.	Interest.	Accumulated total.
1st Year	$7,500,000	$150,750.00	$7,650,750.00
2d "	14,000,000	435,180.08	22,085,930.08
3d "	12,100,000	687,137.19	34,873,067.27
4th "	10,400,000	909,988.64	46,183,055.91
5th "	8,800,000	1,105,159.42	56,088,215.33
6th "	7,200,000	1,272,093.12	64,560,308.45
7th "	5,600,000	1,410,222.20	71,570,530.65
8th "	4,000,000	1,518,967.67	77,089,498.32
9th "	2,400,000	1,597,738.91	81,087,237.23
10th "	800,000	1,645,933.47	83,533,170.70
Total	$72,800,000	$10,733,170.70	

The purposes for which this fund may be drawn upon and the conditions under which operators will be entitled to aid have already been indicated. It is impossible at this time to go into greater detail, except to say that in view of the peculiar character of the ship-operating business and the extraordinary trade conditions likely to prevail during the next five years, the trustee should be allowed to use considerable discretion in the administration of the Merchant Marine Development Fund. Also, it is important to point out that, although new accretions to the fund will diminish year by year, the amounts returned to it by the companies which have weathered the stormy periods of their careers can be relied upon to keep it practically intact. The only losses which need be considered are such as may arise through foreclosures executed against companies which, despite the aid of the fund, have failed to earn their charges.

It cannot have escaped notice that the assistance I propose to render with the Merchant Marine Development Fund takes the place of the Government backing for the development of new trade routes in the national interest, which is the strongest argument brought forward by the advocates of a Government-owned and operated Merchant Marine. Yet not one cent of this fund is drawn from the public treasury. Instead, the money represents profits forborne by the Government, which is not entitled to earn profit while engaged in developing the industries of its people. Neither can it be said that the money will be taken from the steamship business, for in no case will the operators be charged more than the current market rate for similar service, whether the service rendered be insurance or credit.

THE GOVERNMENT DIRECTORS.

The functions of the Government Directors mentioned in connection with the Federal charter under which our steamship companies should operate will be of utmost importance. The provision which prohibits their drawing a salary automatically insures that no great number of them will be men whose interests are centered in the steamship business. At the same time, the provision that the Government shall name them insures that they will be men of standing, sym-

pathetic with American interests and alive to the public-service character of the steamship business. Upon these men the American Merchant Marine will rely to bring about that co-ordination of effort which will insure healthful conditions within each corporation, clean business methods, and, in short, will put each operating unit on its mettle, both in its own interest and in the interest of the American Merchant Marine as a co-operative whole.

These Government Directors, accompanied by members of the operating companies' boards, should meet in Washington quarterly, or at other stated periods. They should form a permanent organization and establish permanent offices. These offices should be the point of contact between the operating companies and the Shipping Board, or other designated Government agency. They should be the clearing house for the operators' periodical statements, and they should be in charge of a secretary who is paid a salary from the Merchant Marine Development Fund.

Immediately upon convening in Washington the Associated Directors should appoint from among their membership a sufficient number of committees to handle all the important problems of steamship operation. There should be a committee on trade routes, a committee on freight rates, a committee on finance, and a committee on organization. These committees should be subordinate to an Executive Council composed of five members who should remain in session after the general meeting of all the Associated Directors, in order to digest the proceedings and recommendations of the meeting and present them in proper form to the Shipping Board, or other designated Government agency.

After consultation with, and upon the recommendation of, the Association of Directors, the Shipping Board, or other designated Government agency, would—

(a) Determine what assistance, if any, should be given from the Merchant Marine Development Fund.

(b) Establish new trade routes, or modify or discontinue old ones.

(c) Determine whether or not a defaulting mortgage should be foreclosed.

(d) Take any steps, or exert any influence, within its power to improve the American Merchant Marine.

NEW LEGISLATION REQUIRED.

In order to make this plan effective it will be necessary to ask Congress for three statutes. One of these statutes should authorize the incorporation of steamship companies under Federal charter along the lines I have indicated. Another statute should extend the emergency power to carry hull and machinery insurance in the Shipping Board's fund so that this function may continue to be performed by some designated Government agency so long as the Government may continue to hold an equity in any of the vessels it now owns or has under contract. The third statute, of which I shall speak at greater length, should revise the present status of vessel mortgages so as to make them attractive to bankers and other investors.

The security of a mortgage may be imperiled by loss or damage to a vessel, or by the attachment of superior liens. Such liens can generally be classed as those arising from debts and from liabilities. The most important ones, resulting from debts, arise from the furnishing of repairs, supplies, or other necessaries in the maintenance and operation of a vessel, including pilotages, towages, port charges, crews' wages, and other contractual obligations. Liabilities creating liens result principally from collisions, strandings, salvages, general averages, cargo damages, and personal injuries. Practically all such liabilities can be insured against by the standard form of marine insurance policies, and by protection and indemnity insurance.

If, therefore, the mortgage contains covenants and agreements to compel the mortgagor to insure against such liabilities, as well as loss from fire and marine peril, the security of the mortgage will only be jeopardized by liens arising from contractual obligations. It is my proposal to obtain protection against the latter by amending the existing law so as to assure to anyone furnishing such repairs, supplies, other necessaries, etc., the opportunity, by exercising due diligence, of obtaining full information by the existence of the mortgage, and then to provide that the lien of the mortgage shall be superior to liens for repairs, supplies, and other necessaries (contractual obligations), etc.

By this co-ordination of mortgage, covenants, and agreements and the statutes, reasonable and adequate protection can be secured to the mortgage. I would provide for such notice by requiring that all mortgages be recorded with the Collector of Customs where the mortgaged vessel is registered or enrolled and that the ship's registry or enrollment have endorsed upon its face the names of the mortgagor and mortgagee, the place of record, and the amount secured thereby.

Such record and endorsement would be made a condition precedent to the validity of the mortgage as against all the world save the mortgagor and mortgagee. If then the owner, master or agent of any vessel apply for the furnishing of repairs, supplies and other necessaries, or for the rendition of contractual services (except for the services of seamen) upon the mortgage of the vessel, the proposed creditor could immediately advise himself of the existence of any mortgage by examining the ship's papers, and could by telegraphic means communicate with the Collector of Customs of the home port of the vessel and ascertain the amount remaining unpaid upon the mortgage. With this information the proposed creditor could determine for himself the advisability of extending the requested credit. If he did so and a foreclosure of the mortgage upon the vessel should destroy his security, he would be without grounds of complaint against the superiority of the mortgage, because he would have furnished the credit with full knowledge of the superior lien of the mortgage.

I would also vest in the United States District Court exclusive jurisdiction over the foreclosure of the mortgages, instead of leaving the mortgagees to their present remedy in the State court. This would make the practice uniform and therefore greatly enhance the security value of the mortgage by providing a speedy and simple method of foreclosure. It would also avoid the inconsistencies, delays and uncertainties of State laws and procedure which now exist. By and large, the enactment of a statute such as I have outlined would make of a mortgage on American vessel property a security fully as good as, and in some respects better than, a mortgage on vessel property sailing under any other flag on earth.

The demand for tonnage, at the present time, is so great that every available ship, including our wooden ships, is in service. The feeling among ship men is that this great demand will continue for at least two or three years. On account of the different variety of service for which wooden ships and steel ships are especially suitable, I have not included the wooden ships in my plan for the disposition of the steel ships.

CONCLUSION.

In conclusion, I have only to say that this plan is based upon profound convictions formed after a close personal study of conditions at home and in Europe, and after careful consideration of the best information I could obtain about what is going on in other quarters of the globe. I have not permitted myself to be guided by the example or methods of other nations, except, insofar, as it has seemed necessary to take cognizance of the results of their acts and methods as conditions which the American Merchant Marine will have to face upon the waters of the five oceans and seven seas. My one thought has been to work out a plan which would be American in conception and adapted to the ideals, genius, temperament and business methods of the American people—a plan sufficiently elastic to serve the enormous extension of overseas trade we have in prospect without having to undergo disorganizing changes. I have just laid the product of my labor before you.

Widening Demand for Blast Furnace Slag

THE commercial possibilities of blast furnace slag have been known for many years in this country, but it has been in Europe that this waste material has long been commercially utilized for a wide variety of purposes. It is only recently that a really active campaign has been conducted by any blast furnace interest to develop new markets so that it may be more fully diverted to useful purposes.

Among the uses which are more or less developed are the following: A concrete aggregate for reinforced concrete buildings; foundations for buildings and heavy machinery; floors, roofs, retaining walls, bridges, culverts; paving, sidewalks, curbs and gutters; dams, reservoirs; cement blocks, bricks, lintels and fence posts; cushions under brick and block pavements, top dressing and surfacing rough roads; filter material for certain chemical processes and sewage disposal plants; as a base or filter for commercial fertilizer and for railroad roadbeds.

The Steel Corporation began the partial utilization of its blast furnace slag shortly after the acquisition of a large cement company. The corporation furnaces produce annually about 10,000,000 tons of slag, but only about 1,500,000 tons of this has up to the present time been used in the manufacture of cement. About 1,500,000 tons has been used annually for railroad ballast, highway construction and as a concrete aggregate and about 250,000 tons annually has been used for filling and other miscellaneous purposes. Thus only about one-third of the total production of slag by corporation furnaces has been commercially utilized, the remaining two-thirds of the product going into dump piles.

This year there was approximately 20,000,000 tons of slag produced by all of the blast furnaces of the United States, figuring 55 pounds of slag for 100 pounds of pig iron. It probably never will be possible to divert all of this slag to commercial uses, but it is the purpose of the Steel Corporation, so far as its own furnaces are concerned, to make slag an asset rather than an expense. At some of the furnaces of the Pittsburgh district the charge for hauling away slag averages 50 to 60 cents a ton.

Recent prices obtained for slag in the Pittsburg district have averaged about $1.05 a ton. While this does not allow much of a profit, it wipes out the expense incurred in dumping the slag as waste material. The price at which slag may be sold is governed largely by current market prices for crushed stone and gravel, with which it competes as a concrete aggregate and in other uses. Thus far it has not been found practicable to ship slag more than 80 or 100 miles from point of production, this being due to the fact that on longer hauls the freight rates make the delivered cost too high.

A serious problem in connection with the disposition of slag as waste, particularly in congested districts, such as Pittsburgh and its environs, is the acquiring of suitable dumping ground. Not infrequently the slag has to be moved many miles from the plant and dumped on ground bought at considerable expense and this land can seldom be used for any other purpose. Considering the cost of haulage and the expense of maintaining the dumping ground, it probably costs many blast furnaces at least $1 a ton to dispose of their slag.

In the search for new ways of commercially utilizing slag the building field offers most promise. Laboratory tests have demonstrated that slag is the lightest form of concrete aggregate available; that its strength is not surpassed by the best stone aggregate, and that its chemical composition is such that it cannot disintegrate, its porous construction and decided angularity giving it superior building qualities. It is declared to be fire-irresistive because it has already gone through the fire of the furnace, and it is also an effective barrier to moisture. The sulphur content, which has been reduced to sulphides by the intense heat of the furnace, is declared to act as a preservative for the steel in reinforced concrete buildings.

Another field which is being carefully developed is the construction of roadways. It has been found that slag is an ideal material for building tar or macadam roadways, or as a cushion for brick, wood block or other paving. It has been successfully used in the construction of concrete sewers. As railroad roadbed and for other railroad work, such as station buildings, retaining walls, bridges, sidewalks, paving, etc., the Pennsylvania Railroad and other roads in the Pittsburgh district have been using slag to a large extent.

For commercial use the steel companies make three kinds of slag. Granulated slag is made by running the hot material as it comes out of the furnace over a water jet, which granulates the slag as it falls into a receptacle. Most of the granulated slag is used as a cement ingredient. Forked slag is simply run out of the furnace in trenches as pig iron used to be and when cool is forked out and dumped into cars. Bank slag is poured into a ladle and hauled to a dumping bank and allowed to season. Later it is dug up by a steam shovel and put through a crusher. There is also a demand for ferromanganese slag, which because of its color, is found desirable by some of the railroads for work around stations.

There are certain economic reasons for the use of slag in place of crushed stone or gravel—reasons which revolve mainly about questions of labor supply. These considerations may be given weight without prejudice to the crushed stone and gravel interests. It would seem that a very large outlet for blast furnace slag might be found in the construction program for roads and other public works which are now being developed by Washington authorities.

If all of the blast furnace slag produced annually in the United States could be disposed of at an average price of about $1 a ton there would be a new income of about $20,000,000 annually from a material which is now largely going to waste. Owing, however, to the limited area in which shipments can profitably be made it is not considered probable that all of the blast furnace slag produced can be commercially disposed of, but an enlarged field of usefulness could be made to turn it from liability a business asset.—*Clarence E. Wright, in Iron Age.*

Mechanics and Electricity[*]

Analogies that Suggest Practical Experiments for the Student

By W. S. Franklin, Lecturer in Massachusetts Institute of Technology

CERTAIN fundamental equations in the elementary theory of electricity and magnetism are identical to equations in mechanics, and this identity of mathematical forms carries with it a group of complete analogies between mechanics and electricity and magnetism. These analogies are familiar to everyone in a vague and incomplete way. The object of this article is to show the use of these analogies in their precise forms, especially in their bearing on alternating current phenomena.

Consider a heavy body which moves without friction. The effect of a force on such a body is to make its velocity increase at a certain rate. Indeed

$$F = M \frac{dv}{dt} \qquad (1)$$

where F is the force (expressed in suitable units), M is the mass of the body, and dv/dt is the rate of increase of the velocity of the body.

Consider an electric circuit or coil which has no resistance. The effect of an electromotive force on such a circuit would be to make the current in the circuit increase at a certain rate. Indeed

$$E = L \frac{di}{dt} \qquad (2)$$

where E is the electromotive force, L is what is called the inductance of the circuit, and di/dt is the rate of increase of the current i in the circuit.

From equations (1) and (2) it is evident that electric current i corresponds to velocity v in mechanics, and that what is called the inductance L of a circuit is exactly analogous to mass M in mechanics. Also it is evident that electromotive force E is analogous to mechanical force F.

Consider a helical spring. The effect of a force F is to stretch the spring; and the elongation q' is proportional to the stretching force F so that we may write:

$$q' = C' F \qquad (3)$$

where C' is a proportionality factor having a definite value for a given spring.

Consider a thin layer of insulating material between two large sheets of metal. Such an arrangement is called a condenser. The effect of an electromotive force E on such an arrangement is to draw a certain amount of electric charge q out of one metal plate and push it into the other metal plate, and q is proportional to E. Therefore we may write

$$q = CE \qquad (4)$$

where C is a proportionality constant which is called the capacity of the condenser.

From equations (3) and (4) it is evident that the electric charge q which has passed through a circuit is the analogue of distance moved, and that the capacity C of a condenser is the analogue of the elastic or yield constant C' of a spring.

In Fig. 1, the hammer exerts very large force on the ball for a very short time, and this force sets the heavy ball in motion very quickly. The ball then continues to move for a relatively long time, slowly compressing the elastic cushion and exerting a comparatively small force on the wall for a comparatively long time. Thus the ball and cushion convert the very large and short-time force of the hammer blow into a comparatively small and long-time force as exerted against the wall.
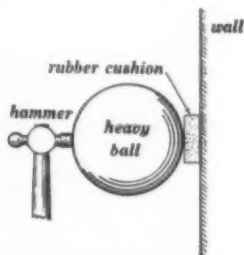

Fig. 1

If the cushion is replaced by a rigid block, and if ball and wall are assumed to be entirely rigid then the force exerted on the wall would be exactly as if the ball were not there.

Analogously, in Fig. 2 when lightning strikes the

trolley wire a very large electromotive force acts for a very short time between trolley wire and ground. This electromotive force sets up a current through the choke coil (an inductance) and this current continues to flow for a relatively long time, slowly charging the condenser and building up a comparatively small electromotive force across the condenser terminals and across the generator terminals. Thus the choke coil and condenser convert the very large and short-time electromotive force due to the lightning stroke into a comparatively small electromotive force of long duration, as acting across the generator terminals.
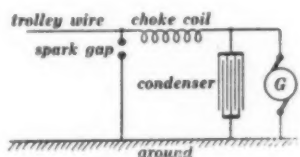

Fig. 2

If the condenser is disconnected, if there is no condenser effect in the end turn of the generator, and if the generator inductance is very large, then the electromotive force exerted across the generator terminals would be exactly as if the choke coil were not there.

A flat spring is clamped in a vise, and the free end of the spring is moved back and forth by the hand. *The end of the spring moves at its maximum velocity in the positive direction one-quarter of a cycle before the maximum pull in the positive direction is exerted upon it.* Similarly, the maximum positive value of current in a condenser occurs one-quarter of a cycle before the maximum positive value of alternating electromotive force is exerted on the condenser.[1]

A heavy weight is attached to the free end of a flat spring the other end of which is clamped in a vise. The weight is set oscillating back and forth and the spring by its bending serves to visualize the force (alternating force) which acts on the oscillating weight. *The weight moves at its maximum velocity in the positive direction one-quarter of a cycle after the maximum force in the positive direction is exerted upon it.*

A light spoon is used to stir stiff pancake batter by a rapid to and fro motion. The force exerted on the spoon by the cook's arm is nearly all used to overcome the resistance of the batter thus doing useful work, and only a negligible portion of the force exerted by the cook's arm is used to start and stop (accelerate and decelerate) the spoon. Imagine a cook trying to stir pancake batter with a heavy iron coupling pin by a rapid to and fro motion. The force exerted on the receiver (the coupling pin) would be nearly all used to accelerate and decelerate the pin, and only a small part of the force would be used to overcome the resistance of the batter. The spoon (or coupling pin) is the receiving device in the above examples, and the cook's arm is the alternator. If the spoon were to fly out of the cook's hand we would have the analogue of dead short-circuit even if the electromotive force induced in movement corresponds to perfect freedom of flow of current. Why, under such conditions does not the cook's hand move back and forth with indefinitely large velocity values corresponding to the very large current values in a short-circuited alternator and wreck the kitchen? Because, even supposing the muscular effort to be entirely unaltered by the "short-circuit" condition, the mass of the cook's arm limits the velocity values in the same way that the internal inductance of an alternator limits the current values on short-circuit even if the electromotive force induced in the armature windings were to be entirely unaltered by the short-circuit condition.

One of the most troublesome things in mechanics is to understand the work or energy aspects of the stirring of pancake batter with a heavy coupling pin. Anyone can understand that very little work is done on the batter, but everyone knows that a great deal of work is done by the cook. The case of the alter-

nator, however, is different; very little work is done by a low power-factor receiver, and *correspondingly little work is done by the alternator.* The important difference between the cook and the alternator is that the cook is not a pure mechanism. The cook's arm cannot be put into condition to do work by forcibly bending it. Or, in other words, to forcibly bend a man's arm is not equivalent to giving the man food. To understand completely the energy relationship between an alternator and a low power-factor receiver one must get far enough away from homely experience to realize that there is a kind of horse that can be fed by driving him down hill. Let our coupling pin be connected to a spring of proper stiffness to accelerate and decelerate the pin, and let the cook exert only the force necessary to overcome the resistance of the batter, then all forcible bending of the cook's arm is eliminated and taken care of by the spring, and the spring can be "fed" by forcible bending.
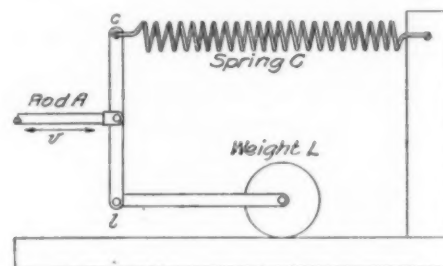

Fig. 3

INDUCTANCE AND CAPACITY IN PARALLEL.

In Fig. 3, an alternating force is applied to the rod A so as to give to it a to and fro velocity v. This velocity divides between the ends c and l of the lever.

An alternative electromotive force produces an alternating current i through A and B. This current divides between the two branches c and l of the circuit.

The following experiments can be performed with the mechanism shown in Fig. 3.

(1) Move the rod A back and forth at low frequency; then the weight L will move, but the end c of the lever will not move perceptibly. *Low-frequency alternating current will flow almost wholly through the inductance L in Fig. 4.*
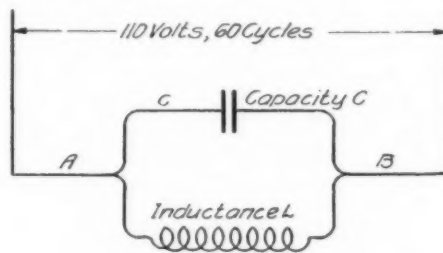

Fig. 4

(2) Move the rod A back and forth at high-frequency; then the end c of the lever will move, but the weight will not move perceptibly. High-frequency alternating current will flow almost wholly through the condenser C in Fig. 4.

(3) Move the rod A back and forth at a low-frequency with a high-frequency movement superposed thereon. The low-frequency movement will show itself almost wholly in the movement of the weight, and the high-frequency movement will show itself almost wholly in the movement of the end c of the lever. This action corresponds exactly to the action of the arrangement for using a single telegraph wire for telegraph and telephone service simultaneously.[2]

(4) At a certain critical frequency a very small to and fro movement of rod A sets up and maintains very large rocking movement of the lever, so that the to and fro velocity of end c and the to and fro velocity of end l are both very much larger than the to and fro velocity of rod A. *A small alternating current of critical frequency at A and B in Fig. 4 divides between the two branches c and l, and the current in each*

[*]The material for this paper, from *General Electric Review*, was largely taken from two books by the above author and B. McNutt, "Electricity" and "Advanced Electricity and Magnetism."

[1]The student of physics who is content with a verbal statement is hopeless; let the thing be actually done. The above statement in italics is not to be taken on authority; get a spring and see for yourself. If this article is to be understood all of the experiments must be seen, or, what is infinitely better, done by the reader.

[2]See Franklin's *Electric Lighting and Miscellaneous Applications of Electricity*, page 245.

branch is much larger than the current at A and B. This effect is called the multiplication of current by resonance.

(5) Hold end c of the lever so that it cannot move, and move rod A back and forth (preferably at the resonance frequency as described under (4), above). Then release end c of lever and note great reduction of motion of rod A for given to and fro movement of weight. This experiment shows how the alternating current in a transmission line (movement of rod A) can be reduced by connecting a condenser in parallel with a low power-factor (inductive) receiver.

INDUCTANCE AND CAPACITY IN SERIES.

A weight attached to the end of a flat spring, the other end of the spring being clamped in a vise, is exactly analogous to inductance and capacity in series. Take hold of the weight and move it back and forth thus bending the spring. Then:

(1) At low-frequency nearly the whole of the force exerted by the hand is used to bend the spring, the force required to accelerate and decelerate the weight is very small in comparison.

(2) At high-frequency nearly the whole of the force exerted by the hand is used to accelerate and decelerate the weight, the force required to bend the spring is very small in comparison.

(3) If low-frequency alternator is connected in series with a high-frequency alternator we get from the combination a high-frequency electromotive force superposed on a low-frequency electromotive force. If such an electromotive force be connected to an inductance and capacity in series, the low-frequency voltage will show itself across the capacity and the high-frequency voltage will show itself across the inductance.

(4) At a certain critical frequency the force exerted by the hand overcomes the resistance only; the force required to bend the spring is at each instant supplied by the inertia reaction due to acceleration and deceleration of the weight, and the force required to produce acceleration and deceleration is at each instant supplied by the reaction of the bent spring. It is correct to say that the alternating force exerted by the hand divides into two parts (one acting on the weight and the other acting on the spring) each of which may be much larger than the whole force exerted by the hand. This phenomenon is called the multiplication of electromotive force by resonance.

Use a strip of window glass as a spring, clamp it in a vise and attach a weight to its free end. Touch the weight with a feather repeatedly at a frequency equal to the frequency of free oscillation of the weight, and a violent state of oscillation will be slowly built up. Eventually the force action on the strip of glass by the inertia reaction of the weight will be large enough to break the glass. This is exactly analogous to the building up of a high voltage across a capacity by resonance so as to break down the insulation of the condenser (capacity).

(5) The use of a stiff spring to accelerate and decelerate a coupling pin which is used to stir batter, so that the cook need only exert the force necessary to overcome the resistance of the batter, is an example of power-factor correction (reduction of low power-factor to unity power-factor) by connecting a condenser in series with an inductance. This arrangement is not used in practice.

THE TRANSFORMER.

Every student of electrical engineering has no doubt wondered what might possibly be the relation between the familiar devices for multiplying force in mechanics and the devices for multiplying electromotive force. A steady force of 110 pounds is easily "transformed" into a steady force of 1,100 or 11,000 pounds by means of a lever; but a steady electromotive force of 110 volts cannot be converted into a steady electromotive force of 1,100 or 11,000 volts by a transformer. Therefore it would seem that the lever and the transformer are wholly unrelated. However, a lever with a heavy weight instead of a fixed fulcrum is entirely analogous to a transformer; and the equations of motion of such a lever can be reduced to forms identical with the equations of a transformer including such complications as magnetizing current and magnetic leakage.

An ideal lever consisting of a weightless bar with an indefinitely large mass as a fulcrum is the exact equivalent of the ideal simple transformer. The to and fro velocities of the ends of the lever correspond to primary and secondary currents, the force (alternating) applied to one end of the lever corresponds to the voltage applied to the primary of a transformer, and the force (alternating) exerted by the other end of the lever corresponds to the secondary terminal voltage of a transformer. The velocity values are directly as the lengths of the two arms of the lever (this corresponds to the fact that the primary and secondary currents of an ideal transformer are inversely as the respective numbers of turns of wire), and the two forces are inversely as the lengths of the two arms of the lever (this corresponds to the fact that the primary and secondary voltages of an ideal transformer are directly as the respective numbers of turns of wire).

When the working end of the lever is rigidly fixed, we have a condition corresponding to open-circuited secondary. In this case the hand-end of the lever will not move perceptibly if the fulcrum mass is very great; but if the fulcrum mass is moderate, the hand-end of the lever will move as the fulcrum mass is accelerated and decelerated. This motion of the hand-end of the lever corresponds exactly to the magnetizing current of a transformer.

If the beam of the lever were without mass the forces at the ends of the lever would be in exact inverse proportion to the lengths of the arms of the lever; but if the mass of the lever beam is considerable or if there are weights attached to the ends of the lever then the lever acts like a transformer with magnetic leakage. Part of the force exerted by the hand is used to accelerate and decelerate the weight at the hand end, the *remainder* of the force exerted by the hand is transmitted to the other end of the lever (being multiplied in exact inverse proportion to the lengths of arms of lever); a portion of the force so developed at the working end of the lever is used to accelerate and decelerate the weight at the working end, and the *remainder* is exerted on the receiving device.

In all of the above the lever is supposed to be frictionless and the transformer coils are assumed to have zero resistance. There is no need to trace out the analogies between mechanical friction and electrical resistance, because, to make the analogy complete, one has to assume that the force of friction is proportional to the velocity of the moving body.
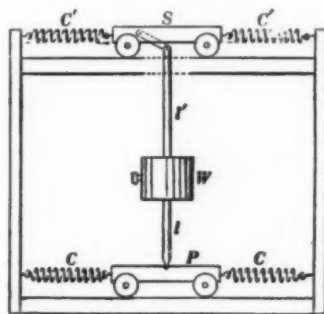
Fig. 5

LOOSE AND CLOSE COUPLING.

Fig. 5 shows a mechanism which is exactly analogous to the inductively coupled (transformer connected) circuits in Fig. 6. Two cars S and P in Fig. 5 are each tied by coiled springs C' C' and C C as shown, and the cars are free to oscillate back and forth on friction rollers. The cars are connected by the vertical lever l l' as shown. Car P with its connecting springs represents the primary circuit in Fig. 6, and Car S with its connecting springs represents the secondary circuit in Fig. 6.[3]
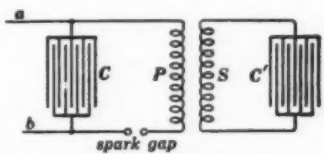
Fig. 6

If the weight (mass) W is large as compared with the mass of either car we have what is called *close coupling.* If the mass W is small as compared with the mass of either car we have what is called *loose coupling.*

If either car in Fig 5 is held fast so that it cannot move, we have what is equivalent to open circuited primary or open circuited secondary as the case may be.

Four modes of oscillation are to be distinguished in the mechanism shown in Fig. 5 (or in the electrical arrangement in Fig. 6). With part of the system held free:

[3] The double pendulum arrangement which is described by Professor F. R. Lyle in the *Philosophical Magazine,* Vol. 25, pages 567-592, is the exact equivalent of two circuits inductively coupled, but the details of the correspondence are not so simple. The usual double pendulum arrangement is not theoretically exact as a representation of coupled circuits.

(a) Oscillation of car P (primary) when car S is held fast (when secondary is open); (b) Oscillation of car S (secondary) when car P is held fast (when primary is open). With entire system free:

(c) Steady oscillation of entire system at high frequency c with velocities of cars opposite at each instant (primary and secondary currents opposite in phase); (d) Steady oscillation of entire system at low-frequency d with velocities of cars in same direction at each instant (primary and secondary currents coincident in phase). These four modes of oscillation are easily shown by the mechanism of Fig. 5.

The most general type of motion of the system consists of modes c and d together; and in this general type of motion the two circuits oscillate by turns and the energy is handed back and forth from one circuit to the other repeatedly. This is easily shown by the mechanism of Fig. 5.

In order that all of the energy of the system may be handed back and forth, from primary to secondary and back again, the two frequencies a and b must be equal. The adjustment for bringing these frequencies to equality is called tuning. Tuning may be accomplished in the mechanism of Fig. 5 by placing weights on car P or on car S. With this adjustment made, car P may be set oscillating and it quickly comes to rest because it gives all its energy to S; then S quickly comes to rest because it gives all its energy back to P; and so on.

If frequencies a and b are not equal and car P is set oscillating, it quickly loses part of its energy as it sets S oscillating; then it takes all of the energy back again and S comes to rest; and so on repeatedly.

In the coupled circuits of the older type of wireless telegraphy, it is desired to get all of the energy from the primary into the secondary. Therefore the primary and secondary should be adjusted to make frequencies a and b equal. When the energy has been handed over to the secondary it must be prevented from being handed back to the primary by open-circuiting the primary by means of the quenched spark. The effect of the quenched spark may be shown by tuning the system in Fig. 5, setting car P oscillating, and suddenly grabbing car P and holding it fast the moment it loses all its energy and comes to rest.

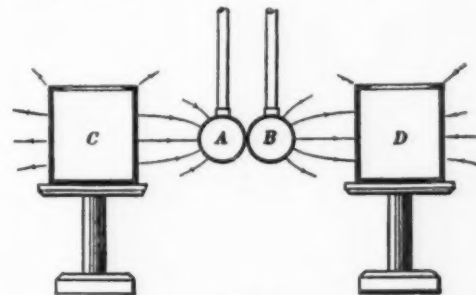The above discussion takes no account of friction and resistance.

Fig. 7

THE ELECTRIC DOUBLER.

Two tin cans, C and D open at top, are supported on insulating stands as shown in Fig. 7. Can C has a small amount of positive charge and can D an equal amount of negative charge, as indicated by the ten lines of force which diverge from C and converge upon D. Two metal balls A and B with insulating handles are placed in contact with each other between C and D as shown, and *a certain fraction of the lines of force from C to D converge upon A and diverge from B as shown.* This fraction is equal to ½ in the figure.

The balls A and B are separated from each other and (1) Ball A is carried to and into can D and touched to the interior of D, and (2) Ball B is carried to and into can C and touched to the interior of C. The result of operation 1 is to string the five lines of force from C to A clear across from C to D, and the result of operation 2 is to string the five lines of force from B to D clear across from C to D; balls A and B being left in neutral condition. The original ten lines of force from C to D have evidently been increased to 15, that is the charges on C and D have been multiplied by 1.5 by the above described operation, and by repeating the operation over and over again the charges on C and D can be multiplied by 1.5 over and over again (leakage on account of imperfect insulation being ignored). Therefore extremely minute initial charges on C and D can be quickly brought up to very large values by 50 or 60 repetitions of the above described operation, because, if the insulation is good, 60 repetitions will multiply the initial charges about one hundred thousand million times, and of course the initial voltage between C and D is multiplied to the same extent.

This experiment must be seen to be appreciated.

Support the two cans C and D on clean blocks of paraffin in a warm dry room. Use best hard rubber or quartz tubes (closed at one end) for insulating handles for balls A and B. Attach a vertical strip of metal to the outer surface of each can C and D, and hang several strands of fine cotton thread over the top edges of these strips of metal. These threads will stand approximately vertical at first, but as the charges on C and D increase they will stand out more and more nearly horizontal.
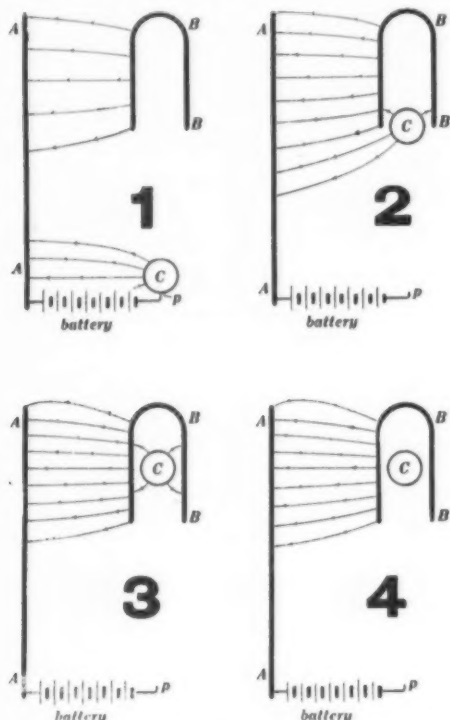

Fig. 8

There is, perhaps, no mechanism which multiplies mechanical force in a manner strictly analogous to the multiplication of electromotive force by the electric doubler. A slight modification of the doubler to give a series of increasing charges (and voltages) which constitute an arithmetical progression instead of a geometrical progression is shown in Fig. 8. The opposite charges on plate A and hollow vessel B are to be multiplied (and thus the voltage between A and B multiplied). A metal ball with an insulating handle is touched to the battery terminal as shown in Fig. 1 and a certain number of lines of force form from ball to plate. Four lines are shown in the figure. These lines are then strung across from A to B by carrying the ball to and into B and touching it to the interior of B as shown in Figs. 2, 3 and 4.

The nearest approach to a mechanical analogue of the doubler as shown in Fig. 8 is to produce an increasing compression on a pack of cards by winding around the pack a string under tension.

ELECTRICITY OR ENERGY; WHICH?

When water is pumped through a pipe it is usually the amount of water delivered in a given time that is important, whereas the amount of power represented by the stream of water is not important except that it must be enough to carry the water where it is needed. But one might conceivably use a pump to drive water through a pipe for the sake of the heating effect of the moving water in the pipe or to drive a water motor placed somewhere in the circuit of pipe. In such a case one would be interested primarily in the amount of power represented by the stream of water because the desired effect (heating or motor driving) would depend upon the amount of power.

So it is in the use of the electric current. It is not electricity (whatever that is) that one uses, it is work or energy; and the important thing about an electric generator (such as a battery or dynamo) is its power output. The almost universal misunderstanding of the matter may be beautifully illustrated by considering the mechanism shown in Fig. 9. A wheel A drives another wheel B by belt. A person knowing nothing at all about machinery, and *especially a person having no available words to use in describing such an arrangement*, might look at the continuous stream of leather coming off wheel A at point p and decide to call wheel A a leather generator, and wheel B a leather motor. Everyone knows, however, that a driving wheel does not generate leather; it gives of work or energy, and the work is transmitted to the driven wheel by the belt.

It seems very ridiculous to speak of a belt wheel as a generator of leather, and it is equally absurd to speak of a battery or dynamo as a generator of electricity. One must be careful not to take electrical terms and phrases too literally.
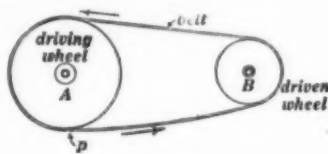

Fig. 9

To speak of a dynamo as an electric generator is common usage and it is therefore not seriously objectionable, but to speak of electricity as a motive power indicates a very serious misunderstanding. When it is proposed to drive a machine by a leather belt it is always understood that something must drive the belt, but when it is proposed to drive a machine by "electricity" it is not always understood that something must drive the "electricity." Electricity as applied in the arts is merely a go-between like a leather belt, and no one ever thinks of leather as a motive power, at least not in the engineering sense, however vivid our memories may be of the motive power of leather in homely sense.

This discussion of mechanical analogies is intended to illustrate the important use of sense material in the building up of physical ideas; indeed the understanding of any principle or relation in physics is a structure which is built up in the mind out of just such stuff, like a house is built of wood or stone. Many teachers, especially teachers of mathematics, seem to think that ideas can be built up in a young man's mind by a sort of hocuspocus, out of nothing; but ideas, like everything else in this world must be made of something, and the problem of the science teacher is, by suggestion or by manipulation and experiment, to drag sense material into the young man's field of consciousness where it may be organized into a structure of ideas.

Industrial Use and Limitations of Respirators, Gas Masks and Oxygen Breathing Apparatus[*]

DURING the last year the Bureau of Mines, Department of Interior, has received many inquiries regarding the use of Army gas masks in the industries for protection against poisonous and irritating gases. These inquiries show a general belief on the part of the public that this type of mask will protect the wearer under all conditions against any gas whatsoever, even in absolutely irrespirable air to the exclusion of the more cumbersome mine rescue breathing apparatus. This erroneous belief will no doubt be further confirmed by millions of discharged soldiers who have been trained in the use of the gas mask and have been taught that it gives them absolute protection against all gases used in warfare or likely to be used. These men will not realize that out in the open air of the battlefield the percentage of gas in the air can never be anywhere near as large as may occur in the confined spaces of a factory operation. A mask may afford complete protection under outdoor conditions and break down at once when used indoors where a gas container has burst and filled the room with a greater concentration of gas. It must also be remembered that the absorbents in the Army respirator, which filter out the poisonous gas, are specially designed for the gases used in warfare, and as a matter of fact do not protect against the more common industrial gases as, for example, illuminating, natural, producer and blast furnace gas.

The Army gas mask never should be used in mines, because of the uncertainty there is of the kinds and amounts of gases in the atmosphere and liability of insufficient oxygen to support life.

In view of these limitations of the Army gas mask, which, if not realized, will lead to serious accidents and fatalities, the Bureau of Mines is issuing this brief statement of the industrial use and limitations of the several dust respirators, gas masks and oxygen breathing apparatus.

DUST RESPIRATORS.

Protection from dust and liquid mists is obtained by the use of a simple dust respirator, which removes these particles by means of a filter of moist sponge, cotton or wool pad, porous paper or even a very fine mesh metallic gauze. The respirator may enclose the mouth and nose only, or it may be combined with a face mask containing eye pieces if the eye must also be protected. The simple "pig snout" respirator containing a moist sponge has been on the market for years. It is highly uncomfortable to wear, rather insufficient for removing fine dust, and most workmen prefer to tie a large handkerchief over their nose and mouth. Some

[*]*Chemical and Metallurgical Engineering.*

improvement has been made in recent years, but on the whole a really efficient and comfortable dust respirator that workmen will wear continuously is yet to be devised. On account of the urgent need of such a device for safeguarding the health of workmen in the mining and metallurgical industries, the Bureau of Mines has undertaken a study of dust respirators with a view to obtaining as satisfactory a model as possible.

The Army gas mask consists of a face piece of rubber and cloth fabric, containing eye pieces and connected by means of a flexible rubber tube to a canister containing charcoal and soda-lime for filtering out the poisonous gas from the inhaled air. The canister is supported in a knapsack slung from the neck.

The Army gas mask is by no means the unusual protective appliance that it is popularly believed. It does not afford universal protection against all gases, nor can it ever be used safely in low oxygen atmospheres. It furnishes no oxygen to the wearer and can only remove comparatively small percentages of poisonous gas from inhaled air, usually less than 1 or 2 per cent. Higher percentages will immediately penetrate the canister and "gas" the wearer. The standard Army gas mask will furnish protection against percentages not exceeding 2 per cent. of the following gases in air: Sulphur dioxide, hydrogen sulphide, chlorine, carbon bisulphide, nitrogen peroxide, aniline vapor, benzyl bromide, benzyl chloride, chloracetone, chlorpicrin, hydrogen chloride, phosgene, sulphur chlorides, xylyl bromide, stannic chloride, titanium tetrachloride and silicon tetrachloride.

It will be seen from the above that the field of usefulness of the Army mask is confined to certain of the chemical industries, around smelters and roasters where sulphur fumes are given off and in the industries using chlorine and bleaching powder. The Army canister also contains cotton filter pads which remove irritating and poisonous dusts, which increases its usefulness around smelters where sulphur and arsenic fumes must be removed.

The Army mask furnishes no protection whatever against carbon monoxide. This is the poisonous constituent of blast furnace, producer and illuminating gases, and of mine gases after fires and explosions in coal mines. Carbon monoxide is also likely to be present in ordinary fire-fighting conditions met by fire departments. Moreover, in all of these cases there is likely to be a deficiency of oxygen. Therefore, for adequate protection against these conditions the oxygen breathing apparatus must be used, and reliance on the Army mask may be fatal.

Ammonia is another gas that will penetrate the standard Army canister. However, a special chemical may be placed in the Army canister which will adapt it for use around refrigerating plants.

OXYGEN BREATHING APPARATUS.

The self-contained oxygen breathing apparatus can never be displaced by the gas mask for use in atmospheres deficient in oxygen. Such atmospheres are encountered in mine rescue work, in gas mains, blast furnace stoves, gasoline tanks, etc. Aside from the lack of oxygen, carbon monoxide is also present, for protection against which the Army mask is useless.

The oxygen breathing apparatus must also be used instead of the Army gas mask wherever there are large quantities of irrespirable or poisonous gases, as for example, in entering a gasoline tank containing some residual liquid, or similar tanks, towers and other closed spaces. The concentration of vapors produced by volatile liquids in closed containers is too high to be entirely removed by gas mask absorbents. The only recourse in such cases is a self-contained appliance in which the wearer does not breathe any of the irrespirable atmosphere.

IMPORTANCE OF TAKING EXPERT ADVICE.

Owing to the many factors entering into the use of protective respiratory appliances, the importance of competent advice on the selection and use of such appliances cannot be overestimated. The fact that the Army and Navy used gas masks has been widely disseminated and its significance is likely to be misunderstood, especially by men who have had some training in their use. It also should be made known that both the Army and Navy used the oxygen breathing apparatus in its appropriate place.

In connection with the Bureau of Mines work of safeguarding the health of miners and workmen in the metallurgical industries, a general investigation of respirators, gas masks and breathing appliances is being undertaken at the Pittsburg Experiment Station of the Bureau. This research will be conducted by experienced chemists and engineers who had charge of gas mask research in the Bureau's war gas investigations and subsequently in the Research Division of the Chemical Warfare Service, U. S. A.

How Old Is the World?

The Various Answers Offered to the Question by Different Schools of Science

By Dr. William Harvey McNairn

THE great problems of the origin and final destiny of things have always loomed large in the minds of thoughtful men. Was there a beginning and will there be an end of the world in which we dwell, are questions of perennial interest to-day, as they were in the time of Plato. From these age-long speculations of the philosophers, aided to a greater or less degree by the observations and experiments of scientists, there arose two antagonistic theories which have long dominated the course of thought. According to the one, the world is of comparatively recent origin, and it proceeded from the mind of the Creator full grown, like Minerva from the head of Jupiter. The other looked upon the world in its present form as a single link in an endless chain of transformation. Of this series there was "no indication of a beginning and no prospect of an end." Either hypothesis not only renders futile any attempt to calculate the age of the earth, but indeed, involves an admission of the uselessness of such an investigation.

But to both of these theories philosophical objections of the most convincing kind can be offered. If there be any meaning in the phenomena of nature which the human mind can decipher, we can read in the records of the rocks a past history extending back for millions of years. On the other hand, the evidence of astronomy and geology alike reveal to us a world and a universe which are slowly but inevitably running down. The final end and catastrophe of the world may be slow in coming, but come it must. And if an end, then a beginning. And since there are certain phenomena which are susceptible of accurate examination, and which seem to offer a measure for geological time, the problem ceases to be a transcendental one, and becomes the legitimate subject for scientific investigation and speculation.

It is not surprising therefore that so profound a problem should have attracted the attention of men of science. It has been most carefully investigated from various aspects, and several of these studies have promise of important results. While it is impossible as yet, to arrive at any definite conclusion as to the number of years which have passed since the earth first took its present form, yet it is of interest to review the advance of human knowledge in this direction, and to weigh the probabilities of an eventual answer to the great question.

But we should first have a clear conception of what it is that we are really trying to solve. Apparently we have no means at present of calculating the time since first, in obedience to creative laws, the earth began its course. It may be that this is one of the questions which the human mind can never answer. And so we do well to confine ourselves to a discussion of what is called geological time, or that period which has elapsed since the geological forces as we know them, weathering, river erosion and the rest, first began to be exerted. This is of special interest as it also represents the time during which conditions have been favorable for the existence of life.

Three lines of investigation merit our attention, even in so short a study of the problem as the present. The first is based upon the results of physical research, the second draws its facts from the observations of the geologists, while the third and most recent of the three depends upon the newly discovered phenomena of radioactivity.

II

There is but one fund of energy in the universe. The faintest ray of light which reaches us from a star in the Milky Way, and the agreeable warmth that radiates from our own fireside are but separate manifestations of the one great, eternal force. At the present time this energy is concentrated at certain points within the universe which we call stars. This concentration is, however, but temporary, for the stars are ceaselessly radiating light and heat and thus reducing themselves to the surrounding dead level.

Our star, the sun, has no refuge from this inexorable fate—it is not eternal. Sooner or later its fierce heat will all have been dissipated into space, and it will become cold and dead,

"And that old common arbitrator, Time,
    Will one day end it."

And the life of our planet is bound up with that of its parent sun. From this luminary is derived the force by virtue of which rivers run and waves rise and fall and those geological processes are carried on which

result in the destruction of old rocks and the formation of new: without it water would cease to flow, the oceans would congeal to continents of ice and life would become extinct. It necessarily follows that the age of the sun is a measure of the maximum life of the earth. Is it, then, possible to measure in years the length of time during which our sun could continue to radiate heat at approximately the same rate as we now experience, neither too hot nor too cold for the existence of life? Lord Kelvin's affirmative answer to this question in 1862 was so incisive and so surprising that the scientific world was at once roused to vigorous argument.

It is evident that if we know the temperature of the sun and the rate at which its heat is being dissipated into space, we have a means of determining how long the atmosphere of the earth has been cool enough for the existence of living things. But it is not so simple a matter as this statement of the case would indicate. It is believed that the cooling of the sun is accompanied by a corresponding shrinkage. Paradoxical as it may seem, this, in turn, gives rise to additional heat, and so the rate of cooling is retarded. Now, taking this into consideration, and putting the present temperature of the sun at 6,000° F, Kelvin concluded that it has been only a matter of about 18,300,000 years that the sun has been at its present degree of heat. It has been conceded that the rate of radiation in the past may have been somewhat different, which might result in a possible lengthening of the time to 30,000,000 years. Many attempts have been made to discredit this result, and many and ingenious have been the suggestions of possible sources of energy which would serve to extend the life of the sun and earth, but it must be confessed that none of them stand the test of rigid analysis, and this result still stands unshaken.

III

When we consider the endless diversity of living forms, and the imperceptible rate at which change has taken place during historic time, we are impressed with the implication of a long series of ages. This was clearly perceived by the great biologists who adorned Great Britain at the time when Kelvin's results were first published, and from that period on their voices and those of their successors have been constantly raised in protest against the inadequacy of the time allowed them by the physicists.

Let me illustrate the point of view of the biologists who insist upon the necessity of having very much greater resources of time in order to enable them to account for the development of species, by reference to the best known family history, that of the horses. In this case we have a record of approximate completeness, extending from the early Eocene to the present. The earliest number of the family was called Eohippus, a small animal, some eleven inches in height, whose remains have been found in the Bad Lands of the Western States. In the rocks immediately overlying those in which its bones occur, there is a series of fossil horses each species of which is a little larger than its predecessor until we have in the modern horse a height up to 64 inches. The total increase is therefore some 53 inches. If the growth still continues, it is so slow as not to show any perceptible results within historic time. Now if we allot time according to a conservative geological system, the Eocene appears to be between 5,000,000 and 6,000,000 years before the modern horse appeared, or allowing five or six years to a generation of horses, we would have about 1,000,000 generations. This means that there would be an increase of about 1 inch in 100,000 years or 20,000 generations, which would be gradual enough to satisfy the biologists. But if this inch be allowed there is a mile which should be conceded for consistency's sake. The horses stand very near the head of the animal kingdom. They represent perhaps its highest physical development, and if it has taken five or six million years to add this cubit to their stature, in what terms shall we estimate the years that must have been required to have produced all this wonderful complexity of form and function from the seed of an ancestor void of organs and microscopic in size?

A similar vision of the immensity of past time is given to the geologist, as he contemplates the work of the cosmic forces as recorded in the rocks. He reads there the story from birth to maturity of lofty ranges of mountains. He sees their summits raising themselves five miles above the sea by degrees so gradual

as to be imperceptible. He sees them gradually disappear, for the everlasting hills themselves are not proof

"against the tooth of time,
    And rasure of oblivion."

Little by little the solid rock is crumbled to sand. Grain by grain that sand is carried by wind and rain and river to the great sea, until where once the mountains stood there stretches a rolling plain. Even this great cycle of changes does not represent the whole extent of geological time, for the growth and decay of mountains has taken place many times since the beginning, and in fact, may be completed within a comparatively short division of the whole. How inconceivably long then have been the ages which have passed since first the rivers began to flow and the earth became an abode of living things. And it is surprising that both the biologist and the geologist should have been so impressed by these concrete facts that even the apparently flawless reasoning of the physicists has failed to convince them?

In order to attain some measurable representation of the extent of geological time, recourse was had to two different geological processes: the formation of stratified rock and the accumulation of salt in the oceans, and both of these have been studied with the greatest care and with results of steadily increasing accuracy.

The calculation of age from the thickness of sedimentary rocks is based upon the fact that the material of which they are composed was carried down by the rivers and deposited under the shallow water which surrounds the continents. If we could measure the total depth of all such accumulations, and if we could gage the average load of mud and sand and gravel that goes down to the sea with each year's quota of river water, the problem that we are trying to solve would resolve itself into one of simple division.

But the measurement of this total thickness is an exceedingly slow and complicated process. As long as the accumulated sediments continue to be submerged, their depth cannot be determined, but as the sea level is constantly changing, what was once the bed of the ocean, now becomes dry land. Even under these conditions it is not possible to attain our objective until a river has cut a gorge, or the hand of man has quarried away portions, so that the edges of the rock layers come into view. If we could find somewhere such an exposure of rock which had been accumulating ever since the sea first received the contributions of the streams, it would be an easy matter to measure the total thickness of sedimentary rock, but no such simple measurement is at our disposal. The observations of innumerable small sections must be laboriously fitted together to construct one comprehensive whole, and thus the total accumulation of sediments determined. The latest and best figures available put it at 335,000 feet, or about 64 miles.

We have now to determine the rate at which these sediments are accumulated. This is a problem even more difficult than the previous one. It involves careful observations of the amount of solids carried each year by the rivers. These studies are still being carried on notably by the American Geological Survey, and constantly bring us closer to the standard of essential accuracy. Next we require to know the total area over which these sediments are being deposited, and thus the annual rate attained. This has been set by some observers at 3 inches per century, which would make the time requisite to form the total 134 million years; by others it has been placed at 4 inches per century, which would give us 100 million, and by others still at five inches, with a consequent reduction of time to 80 millions of years.

The other method, a most ingenious one, was first made use of by Professor Joly of Dublin University in a paper published in 1899. It is based upon the theory that the saltness of the sea is due to the fact that ever since they began to flow, the rivers have been carrying salt in solution down to the oceans, and while the water comes back in the form of the rain, the bulk of the salt still remains and so the sea ever becomes salter. It is evident that if we knew the amount of salt now in the ocean and the rate at which the rivers have been delivering it, the length of the time occupied by the process is a matter of very simple calculation. Unfortunately, however, the initial figures are most difficult of attainment. The best measurements at present available set the amount of sodium in the

seas at 14,130 billion tons, and each year the 6,500 cubic miles of water which the rivers contribute, have dissolved in them 175 million tons. These are the basic figures, but certain allowances have to be made. The salt breezes do carry a small portion of salt with them, and a part of the accumulation of past ages does not remain in the sea but is stored away in the form of rock salt. After all necessary corrections have been made, the final result gives a period somewhere between 80,000,000 and 150,000,000 years, with the weight of evidence tending rather toward the smaller figure.

IV

The discovery of radioactivity has had many unexpected results in all branches of science, not the least interesting of which are those bearing upon geology. It even appears that we have in this way a method of determining the age in years of any given rock stratum.

Among those elements which are known to undergo the mysterious change due to disintegration of the atom, is uranium. By giving off particles of helium at a constant and definite rate, uranium is believed to pass over into radium and lead. If in any given uranium-bearing mineral we can determine the relative proportions of uranium, radium and helium, and lead if it is present, knowing the rate at which these changes take place, we should be able to determine the age of the mineral itself.

This method was first suggested by Sir Ernest Rutherford in 1906, who found, in a mineral he was studying, an amount of helium which would indicate an age of 241 million years. Unfortunately he did not state the geological horizon in which the mineral was found, so that the results, so far as our problem is concerned, were of value merely on account of their suggestiveness.

But the lack, which geologists felt was so much to be regretted in this research, was subsequently made good by the Honorable R. J. Strutt, in the careful experiments which he made to determine the ages of a series of minerals whose positions in the geological time scale were definitely known. His results were somewhat startling in the unexpectedly great periods of time which they indicated. For instance he allotted the very respectable antiquity of 141 million years to some rocks which were found overlying carboniferous strata, or about half way down to the earliest fossiliferous deposits. However, these first figures were not uniform, and it remained for subsequent investigators to add their quota. Of recent years these have been tabulated and indicate a certain amount of consistency, particularly in their unanimity in extending the reach of geological time to an extent undreamed of by the geologists. Who, for example, would have dared to suggest from geological evidence alone, that we have to do with periods of from 800 to 1,600 million years?

It is perhaps too soon to accept unreservedly these methods and these deductions. No doubt the physicists are over sanguine when they say that "every uranium bearing mineral is like a clock ticking out its age in molecules of helium and lead." So that our judgment on this work too must for the present remain in abeyance, waiting for fuller and time-tested information.

V

We have thus obtained the opinion of three schools of investigators as to the extent of geological time. One tells us from 10 to 30 million years; the second, about 100 million and the third, anything up to 1,600 million. We must admit that we have not advanced very far. The mean of 10, 100 and 1,000 is a figure of little value. But we have not yet reached finality in any one of the three investigations. The bounds of knowledge are yearly becoming wider and we may hope that even this profound and perplexing problem will one day be solved.

But there is a sense in which 10, 100 and 1,000 are approximately the same—that is when they are compared with infinity. The number of the years of time and space and force we believe is infinite. In the great abyss there has floated for 100 or 1,000 millions of years, perhaps even more, the minute speck of matter which we call the earth but in the light of infinity this is but a momentary phase. "The created world is but a small parenthesis in eternity."

It has already been explained that the information at our disposal does not, at the present stage of human knowledge, offer us much hope of finally determining the time since the earth first came into existence. It does however give us in some slight measure a conception of what this may be. And following the reasoning of Professor Joly of Dublin, we are led to a most interesting and pregnant thought. To-night we see a myriad stars shining in the sky, and the photographic telescope reveals many millions more. It is true that

there is evidence of dark bodies—dead stars, but most of them are still glowing. Since the life of a star is but an evanescent flash in the dark when compared with the infinity of time, it appears that the whole universe came into being at one time, and that all the stars, including our own—the sun, will be snuffed out together. Thus it follows that the measure of the age of our earth as the abode of life is a measure of the life of the universe, and our study of geological chronology has led us to a contemplation of cosmic time. The investigation is yet in its infancy. Who can foretell how great may be the discoveries which science will yet wrest from the storehouse of Nature? What may we not learn about what Carlyle so eloquently speaks of as "that great mystery of Time, were there no other, the illimitable, silent, never-resting thing called Time, rolling, rushing on, swift, silent, like an all-embracing ocean tide, on which we all and the Universe swim like exhalations, like apparitions, which are and then are not; this is forever very literally a miracle; a thing to strike us dumb—for we have no word to speak about it."

McMaster University, Toronto.

Molecular Association and Chemical Combination

of the vapor of the compound, and consequently the state of this compound itself, will then be greatly changed by the presence or the absence of the component in the free state.

If the compound is in the solid state it cannot exist except in an atmosphere whose composition must remain comprised between two limits which, for the same "interval of stability," will be closer together in the case of a mono-atomic component than they would be in the case of a polymerisable component.

We can better comprehend the preceding statements if we consider the example of the hydrates. In the hydrates water behaves upon the whole like a simple non-polymerisable body, since in becoming dissociated the hydrate liberates water vapor. The hydrates are compounds which are but slightly stable. When placed in a too humid atmosphere they are deliquescent; in a too dry atmosphere they become efflorescent. However, since water is a liquid which is not very volatile it is not possible at a given temperature greatly to increase the pressure of the vapor of water in the atmosphere in contact with the hydrate.

Other things being equal the compounds of the mono-atomic gases would be more unstable, since in this case the nonpolymerized component being a gas, at a temperature above its critical point, its pressure might be anything at all.

If the mono-atomic component has a very high critical point the existence of fixed compounds in ordinary conditions again becomes possible; for in this case the component is in the state of extremely dilute vapor which the slightest increase of pressure would condense. The interval of the possible variations of its pressure becomes extremely reduced. The compounds then have nothing more to fear, so to speak. They would be sensitive to the variations of pressure of the component, but since such variations cannot occur they behave definitely like fixed compounds.

These conclusions are fully verified by experiment. The rare gases of the atmosphere (helium, neon, xenon, and krypton) are mono-atomic, as is revealed by the measurement of the ratio of the two specific heats (Langlet, Ramsay and Travers). They are chemically inert.

According to direct measuring of the density of vapor (Ritz, Dewar and Dittmar, Wartenberg), by tonometry in mercury (Ramsay), and also by kryometry in tin (Heycock and Neville), the conclusion has been reached that the majority of the metals are mono-atomic. The metals are capable of yielding stable compounds because their extremely slight degree of volatility prevents them from having any possible influence upon their compounds.

The bodies which are poly-atomic in the free state are always capable, on the contrary, of yielding fixed compounds. They abandon their state of molecular aggregation in order to enter into combination. Their pressure becomes less but their degree of fixity is augmented. In the case of these bodies the state of maximum simplicity of the molecule is a remote condition corresponding to an extreme degree of dilution, and one which is not affected except almost imperceptibly by the variations of other states.

In the preceding remarks we have supposed that the dissociation of compounds was at least upon the point of beginning. It is not impossible, therefore, that the mono-atomic gases may be endowed with an activity of some special nature of such a character that the

compounds formed are completely indissociable in ordinary conditions. This supposition would explain the possibility revealed by the study of radio-active phenomena of the presence of helium as a constituent element of certain metals.

Four Tons of Lead in Paint for Ship

R. C. MONTEITH, painter foreman at the Foundation Company yard, Tacoma, Wash., has figured out, says the *Foundation Shipbuilder*, that the following material from the paint shop goes into each Ferris type ship:

One hundred dollars worth of paint brushes, three barrels of creosote for the frames and deadwoods; 3½ tons white lead; ½ ton red lead for iron work, one ton putty, 225 gallons linseed oil, 50 gallons turpentine, 175 gallons copper paint, 10 gallons stack black for engine rooms and stacks, 20 gallons varnish, five gallons shellac, 150 pounds tints, 110 sacks cement for seams and holes, with two yards of sand and gravel for deck floors.

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